Chapter 11

Safety and Security

Chapter abstract

Summary: ESS will be designed to a high level of safety in order to meet the expectations of the users, the personnel and the regulatory requirements. This applies to aspects of safety such as radiation, fire, cryogenics, chemicals, heavy loads and other hazardous items or situations. The security of the facility will be designed to meet the basic in-house security rules and regulatory requirements, as well as the need from the users and personnel to work in an open and friendly atmosphere.

Licensing of ESS is focused on the regulatory radiation safety requirements from the Swedish Radiation Safety Authority (SSM). Thus, the chapter mainly deals with the radiation safety principles for ESS design. The fundamental safety functions, the safety barriers and the safety systems are generally described.

Passive safety is the fundamental safety principle. The accelerator proton beam hits the target material and neutrons are produced in the spallation process. When the proton beam stops, the production of neutrons stops. Residual heat is removed from the tungsten target by passive conduction, convection and radiative cooling, even without any active systems.

Three confinement barriers contain the substantial nuclide inventory in the target, caused by proton bombardment. All possible other nuclide inventories at ESS will have at least two safety barriers.

11.1 Safety principles

ESS will be a complex facility with the potential to pose a variety of hazards to human beings and the environment. ESS prioritises prevention of harm to employees, the public, and the environment from both radiation and conventional safety threats. In 2011, ESS formally adopted the following project-wide set of *general safety objectives* (GSO) [391]:

- "To protect individuals, society and the environment from harm arising from the construction, operation and decommissioning of the ESS facility.
- To ensure that in normal operation, exposure of personnel to hazards within the facility is controlled, kept within prescribed limits, and minimised.
- To prevent accidents with high confidence.
- To ensure that any abnormal operational event has minimal consequences for ESS personnel and for the public.
- To minimise the hazardous waste arising from the operation and decommissioning of ESS, both in its quantity and level of hazard potential."

These overarching goals will guide ESS through all phases of its multi-decade life-cycle, through all stages of conceptual and detailed design, fabrication of components and construction, commissioning, operation, planned and unplanned maintenance, and eventual dismantling and decommissioning. The GSO govern the design and implementation of the specific safety systems and programmes.

In accordance with well-established international best practice, a few basic principles constitute the framework for the ESS safety programme: exposure to hazards will be *as low as reasonably achievable* (ALARA); multiple and redundant levels of safety barriers and protective systems will provide *defence-in-depth*; ESS design will incorporate both *passive* and *active* safety measures; and an ongoing process of *review and assessment* of safety systems will shape the entire engineering design process. These principles will enforce the *safety culture* within the ESS organisation. Maintaining that safety culture will be a top priority for ESS management.

As low as reasonably achievable

ESS will keep exposures to hazardous materials as low as reasonably achievable. The ALARA principle means that ESS will make every reasonable effort to minimise exposure to radiation, even when exposure falls far below dose limits prescribed by Swedish law (as will usually be the case). ESS will operate on the principle of achieving the lowest level of exposure that is consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the financial cost of achieving further reductions in exposure, and the impact of further reductions on the project's scientific objectives. Application of the ALARA principle implies that predicted doses (during the design phase) and actual doses (during operational phases) should generally decrease as the project proceeds and new data become available, permitting more precise and more realistic estimations of dose levels. ESS will maintain documentary records of the predicted and measured personnel and environmental exposures, in accordance with Swedish law and International Committee for Radiation Protection guidelines and as a necessary step for implementation of ALARA best practice.

Review and assessment

Throughout the engineering design process, ESS personnel will conduct safety reviews and assessments to ensure that the design satisfies the top-level safety objectives and is in compliance with SSMFS 2008:27 [682]. These assessments will include analyses of: normal operation; maintenance; incidents and accident scenarios; waste handling and waste storage; commissioning and test operation; and decommissioning. The results of these analyses will be available to assist the preparation of documentation for regulatory applications.

Safety culture

No set of protocols, rules or laws by itself can guarantee the safe operation of a complex facility. Organisations have cultures, and those cultures affect the safety of their operations. INSAG [683] described a "safety culture" as:

> "...that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, ...safety issues receive the attention warranted by their significance."

Indicating the importance of this issue, a subsequent INSAG report [684], offers recommendations to tackle the practical and managerial challenges to building and maintaining such a safety culture. The management of ESS embraces the INSAG recommendations, and is committed to fostering a safety culture that nourishes an open and constructive attitude towards safety concerns and an organisation-wide commitment to a continuous process of safety improvement.

Quality assurance management

High quality of design, materials, structures, components and systems, operation and maintenance is vital for the overall safety of ESS. Quality assurance programs will ensure the development of a safe design (including design of process and safety systems, design of safety barriers, design of modifications and safety analysis). Appropriate conservative assumptions and safety margins will be used for design and construction.

11.1.1 Confinement barriers and defence-in-depth

Safety engineers at nuclear facilities such as power plants have refined and developed the concept of "defence-in-depth" through years of practical experience. The approach allows facilities to compensate for potential human and technical failures by building several levels of redundant protection into the facility design, including sequential safety barriers to prevent the release of radioactive material to the environment. A failure at one level of a system is compensated by the barriers in place at the next level. While nuclear facilities pioneered the defence-in-depth approach, it can be and has been fruitfully applied to other types of facilities. ESS will use a set of physical confinement barriers that operate independently of one another to prevent and mitigate potential releases of radioactive isotopes. Demonstration of the adequacy of this set of barriers is an important part of the safety analysis. ESS will apply the defence-in-depth concept in order to minimise deviations from normal operation, to prevent accidents, and to mitigate the consequences of abnormal events.

In accordance with the principles laid down by the International Atomic Energy Agency working group INSAG (International Nuclear Safety Advisory Group), ESS will implement the defence-in-depth approach via four safety levels with procedures and systems: to minimise deviations from normal operation; to monitor and document deviations from normal operation and to intervene *before* such deviations progress to accidents; to control accidents if they do happen; and to mitigate the adverse effects of accidents. Table 11.1 provides more detail about this multi-level approach to safety. ESS has chosen to apply the defence-in-depth strategy, which implies that there will be confinement barriers in different parts of the facility. The confinement barriers are shown in Table 11.2.

Passive safety systems

Passive safety systems rely on facility features whose very nature acts to prevent accidents or to limit the adverse consequences of accidents. Passive safety systems rely predominantly on natural laws and material properties, and provide protection independently of human intervention. The ESS design constitute of two such fundamental characteristics of passive safety systems. The first crucially important feature of ESS's design from the safety perspective involves the linear accelerator. The linac will depend on the continuous input of power from the electrical grid to produce beam. This is a powerful safety feature, because if the external power supply is interrupted for any reason, the accelerator will automatically shut itself down. Unlike nuclear reactors, there is no danger of ESS "going critical" once it has been accidentally or deliberately cut off from the power grid. The second important feature of the ESS design from the

Level	Objective	Tool
1	Prevention of abnormal operation and failures.	Conservative design and high quality in construction and operation. Qualification of materials in the target environment. Continuous survey and documentation during manufacturing and testing. Simple operation to reduce probability of human error. Redundancy, diversity and separation principles in active safety systems. Qualification of personal in all life-cycle phases. Quality assurance system covering the safety related activities by ESS and the subcontractors and partners.
2	Detection of deviations from normal operation and provision of means to prevent development of sequences leading to accident conditions.	Independent or redundant control, limiting and protection systems as well as other surveillance features including environmental radiation monitoring.
3	Control of accidents.	Engineered safety features and protection systems to prevent accident progression. Radioactive materials confined within a containment system.
4	Control of severe accident conditions and prevention of accident progression.	Procedures for mitigation of accidents in order to ensure that radioactive releases are kept as low as reasonably achievable.

Table 11.1: Levels of defence-in-depth to compensate for potential human and technical failures..

System	Number of barriers	Confinement barriers
Target	3	Target wheel envelope Monolith confinement Target building
Target systems	2	Monolith confinement Target building
Hot cell	2	Hot cell confinement Target building
Proton accelerator	2	Accelerator beampipe Accelerator tunnel
Neutron scattering instruments	3	Neutron guide shielding Neutron guide tunnel and bunker Instrument component confinement
Waste disposal building	2	Cask/package Building

Table 11.2: Confinement barriers for radiological protection.

safety perspective involves the cooling function of the ESS target station. The most likely reason for a loss of cooling system function is an electric power interruption. Although this guarantees an instantaneous shut-down of the accelerator, heat production in the target will continue for some time. ESS's adoption of a rotating, helium-gas-cooled tungsten target of 2.5 m diameter, which offers a large enough surface area for passive radiative cooling to avoid dangerous temperatures with a significant safety margin, passively eliminates this risk, even in the absence of an active cooling system.

Active safety systems

ESS's active safety systems will include mechanical, electrical and instrumentation and control components. They will ensure that the facility operates safely, and that safety is maintained in the event of an incident. For example, active safety systems will provide for cooling of the target material during normal beam operation. Other active safety systems will make sure that the beam is shut down and that components such as the target material are cooled in the event of an incident. Note that cooling of the target material will be done actively by gas cooling although from a defence-in-depth perspective, this function is not formally required since the cooling can be done passively. Active safety systems also encompass ESS protocols governing installations and training programs to ensure that all employees act in accordance with prevailing instructions and in compliance with Swedish regulation SSMFS 2008:27 [682]. ESS protocols will lay out a fixed schedule for maintenance, testing and adjustment of many mechanical and electrical safety devices, and for radiation monitoring of the experimental instruments.

11.2 The licensing application and regulatory processes

While ESS is a non-nuclear facility, it will produce activated materials. In developing its safety programmes, ESS has profited from decades of collaboration and exchange among regulators and facility operators within the nuclear community about how to handle such materials. The International Atomic Energy Agency (IAEA) is an important actor in this exchange, publishing reports and guidelines that analyse crucial safety issues, summarise the lessons learnt from industry experience, and establish best practices. This accumulated collective knowledge base informs ESS's own safety objectives and programme.

The licensing process of ESS is given by three different legal acts in Sweden, as shown in Figure 11.1; the Radiation Protection Act, the Environmental Code and the Planning and Building Act. In March 2012, ESS sent in the formal application to the Swedish Radiation Safety Authority (SSM) asking for a permit to construct. The Preliminary Safety Analysis Report (PSAR) [685] constitutes the basis of the application. The PSAR describe the overall technical concept, potential risks and the mitigation of those risks and the waste management of the radioactive material. In March 2012, ESS also sent in an application to the Swedish Environmental Court asking for permissibility to construct and operate ESS outside Lund. An Environmental Impact Assessment (EIA) forms the basis for the application. Continuous work has been done for the facility planning layout process towards the Lund municipality in accordance with the Planning and Building Act. In these matters, ESS has a strong connection and cooperation with both Max-lab and the Lund municipality regarding the planning of the whole area northeast of Lund.

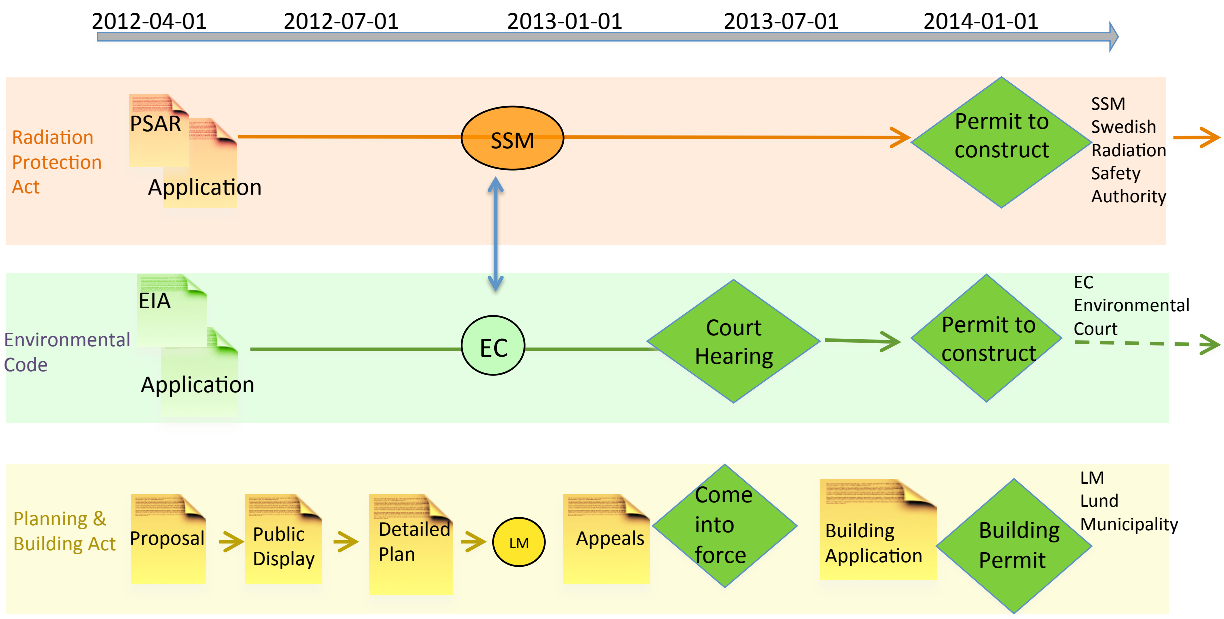

Figure 11.1: Licensing process for construction permits.

Radiation regulations

The Swedish Radiation Protection Act (SFS 1988:220) governs activities and facilities emitting radiation in Sweden. The main purpose of the act is to protect humans and the environment from the harmful effects of radiation. Under power conferred by the act, the Swedish government has issued Radiation Protection Government Regulation (SFS 1988:293). In its turn, under power conferred by this regulation, the SSM has issued a large number of authority regulations supplementing the Radiation Protection Act and Government Regulation. For nuclear facilities, the Nuclear Activities Act (SFS 1984:3) applies. However, ESS does not qualify as a nuclear facility under the definition laid out by the Nuclear Activities Act. Under both the Radiation Protection Act and the Nuclear Activities Act, SSM is appointed as the regulatory authority.

A number of SSM regulations apply to ESS. These include SSMFS 2008:27, which regulates the operation of accelerators and sealed radiation sources; SSMFS 2008:51, which provides for the protection of workers and the public during activities involving ionisation radiation; SSMFS 2008:52, as amended by SSMFS 2010:1, which provides for the protection of outside workers who work with ionising radiation; and SSMFS 2010:2, which regulates the handling of radioactive waste and releases from activities with open radiation sources. In addition, the Swedish Civil Contingencies Agency (MSB) Regulation MSBFS 2011:1, on road and terrain transports of dangerous goods (ADR-S), will apply to the transport of radioactive substances to and from ESS. In the SSM regulations that apply to ESS, there are no specific regulations regarding accidental conditions, although both SSMFS 2008:27 and SSMFS 2008:28 require regulated facilities to develop an action plan for handling unexpected events from a radiation protection point of view.

SSM may, when granting a permit under the Radiation Protection Act, or at any point during the term in which the permit is valid, set permit conditions for ESS. While ESS is not a nuclear facility, it has taken into account those aspects of nuclear facility regulation that seem relevant to ESS activities in developing its own internal protocols and guidelines, which in many circumstances are more stringent than the national regulations [617]. ESS has declared that it will abide by the intention of this regulation. ESS has set 0.05 mSv as the upper annual dose limit for the general public, but aims at not exceeding 0.01 mSv per year for any of three exposure pathways: direct radiation, inhalation and ingestion.

11.3 Radiological safety

The radiological safety focuses upon limiting the doses for the ESS personnel as well as the environment. The limitation and estimation of radioactivity doses are based on regulations from SSM for facilities with major radioactive inventories. In particular, SSMFS 2008:17 requires that "events" be classified according to the probability of occurrence, and specifies that reference doses be established for each event class, which should not be exceeded. ESS has also taken into account experience from similar facilities around the world. The limiting doses are established for normal operation and for different hazardous events, which might occur during the lifetime of the spallation neutron source.

Classification of events

All possible incidents and accidents that might happen at the ESS facility, including normal operation, are categorised into four classes depending on the predicted annual frequency of such events. The classification of the events is presented in Table 11.3, using frequency values adopted from licensing practice in Western Europe [686]. The definitions of event classes are given below and the list of initiating events with their classification is provided in the document setting out ESS's *General Safety Objectives* [391].

- **H1: Normal operation.** Normal operating regime includes different maintenance phases of the facility, including events and disturbances during the normal operation occurring more or less frequently but where a relevant safety system is available. The restart of the facility can be done after repairs that fall within the range of normal maintenance.
- **H2: Incidents.** Events which are unusual, but which are expected to happen at some point during the lifetime of the ESS facility are classified as incidents. The expected frequency of these events varies from 10^{-2} times up to less than once per year. The facility should be able to restart after several weeks of repair following an incident.

Event	Description	Frequency [1/y]	Unit	Rad. workers	Non-exposed workers	Public (effective dose)
H1	Normal operation	≥ 1	[mSv/y]	10	0.05	0.05
H2	Incidents	10^{-2} – 1	[mSv]	20	0.5	0.5
H3	Unexpected events	10^{-4} – 10^{-2}	[mSv]	50	5	5
H4	Design basis accident	10^{-6} – 10^{-4}	[mSv]	100	50	50
–	Beyond design basis accident	$\leq 10^{-6}$				

Table 11.3: Classification of radiation hazard events and summary of the General Safety Objective limits on radiological doses.

- **H3: Unexpected events.** Events that are not expected to occur during the lifetime of the ESS facility are classified as unexpected events. The predicted frequency of these events varies from 10^{-4} to 10^{-2} times per year. The facility should be able to restart after several months of repairs following an unexpected event.
- **H4: Design basis accidents (DBA).** Events which are very unlikely to occur within the lifetime of the facility are classified as DBA events. The predicted frequency of these events ranges from 10^{-6} to 10^{-4} times per year. The facility will be designed and constructed to withstand DBA events, within specific limits.
- **Beyond design basis accidents (BDBA).** Events which are not expected to happen within the lifetime of the facility are classified as BDBA events. The frequency of these events is less than 10^{-6} times per year. The facility probably would not be able to restart after a BDBA.

The commissioning process will include conservative and realistic assessments of the facility's capacity to cope with normal operation, incidents, unexpected events and DBA events. BDBA events have such a low probability that they will not be included in the commissioning safety assessments. Nevertheless, BDBA events will be analysed during the ESS design phase in order to evaluate alternative emergency response scenarios by the relevant authorities. As part of this analysis, ESS will estimate the potential radiological impact of BDBA events. Preliminary evaluations indicate that the radiological impact of BDBA events would not be dramatically larger than that of the DBA events that the facility will be designed to withstand.

General radiation safety requirements

Under Swedish law, the regulations regarding risk and exposure limits for ionising radiation are different for employees and the general public. The summary of the GSO for radiation hazards towards workers with risk for exposure to ionising radiation, non-exposed workers at ESS as well as general public together with the collective dose for ESS staff is presented in Table 11.3. The upper dose limits for H1-H4 events are also provided.

Staff

ESS employees are divided into two classes: those who might be exposed to ionising radiation during their duties and non-exposed employees. The latter group will not have access to areas where there is a risk for radiation exposure. In accordance with Swedish regulation SSMFS 2008:51, the maximum annual effective dose for workers shall not exceed 50 mSv, while the cumulative dose over five years is limited to 100 mSv. Swedish law requires that employee doses be individually monitored, and that doses be monitored online in real time during an employee's presence in radiation risk areas. The Swedish regulations [687] prescribe an annual effective dose limit of 1 mSv for employees who are not exposed to radiation.

In accordance with the ALARA principle, ESS guidelines call for more restrictive dose limits than does Swedish law [391]. For ESS employees whose duties might subject them to radiation exposure, dosage should not exceed 10 mSv per year. The ESS goal for non-exposed employees is 0.05 mSv per year. In addition to the individual dose limits for ESS workers, ESS has adopted a maximum collective annual effective dose, which includes exposures for subcontractors, consultants, and other non-employees present at the facility. ESS has set this collective limit at 1 personSv per year. ESS will also comply with Swedish exposure limits for pregnant women, in accordance with SSMFS 2008:5 [687], which requires that once the employer becomes aware of the pregnancy, the maximum effective dose to a foetus may not exceed 1 mSv during the remainder of the pregnancy.

In case of incident conditions, the Swedish regulations for employees working with ionising radiation is taken as a reference. In accordance with SSMFS 2008:51 [687] the maximum annual effective dose must not exceed 50 mSv, while the total obtained dose during five years has to be lower than 100 mSv for employees. ESS guidelines again set a more restrictive limit of 20 mSv per year. Since there are no governmental requirements related to dose limits for non-exposed workers, ESS guidelines call for the same dose limit as for general public, namely 1 mSv per year [687]. ESS will also comply with the Swedish regulatory requirement that rescue efforts that could lead to an effective dose higher than 100 mSv, may only be performed by volunteers in possession of valid scientific information about the radiation danger.

The public and the environment

Under SSMFS 2008:51 [687], the effective annual dose limit for individuals from the general public who do not work with ionisation sources shall not be higher than 1 mSv. In specified exceptional circumstances, SSM allows for a higher effective dose for a single year provided that the average over five consecutive years does not exceed 1 mSv per year. Again, ESS guidelines call for more restrictive dose limits than does Swedish law, with 0.05 mSv as the upper annual dose limit for the general public. The doses to a representative individual must be estimated with appropriate documentation of methodology. In July, 2012, ESS submitted a dose assessment report to SSM describing likely exposure of the representative person including living conditions, food pathways and a statistical analysis of meteorological dispersion conditions. The analysis demonstrated adequate protection of the environment and biosphere [688]. The results from the activation calculation performed [618] show that ESS radiation emissions will not harm any species or the ecosystem as a whole.

The maximum effective dose for general public must not depend on incident or accident conditions. ESS will estimate release doses for H2 events, and will describe in detail the steps to be taken to mitigate the consequences of releases during such events. In general, SSMFS 2008:51 [687] stipulates that the annual effective dose from H2 events shall not exceed 1 mSv per person who does not work with ionisation sources. In exceptional circumstances, SSM allows for a higher effective dose for a single year provided that the average over five consecutive years does not exceed 1 mSv per year. The calculation results of the released doses under accident conditions will help to determine which measures ESS should apply to mitigate accident consequences and protect employees and the general public. In accordance with [391], ESS guidelines call for the following maximum effective doses to the public: 0.5 mSv/event for H2 events, 5 mSv/event for H3 and 50 mSv/event for H4 events.

11.3.1 Safety functions

The IAEA [689] has identified three fundamental safety functions that,

> "...shall be performed in operational states, in and following a design basis accident and, to the extent practicable, on the occurrence of those selected accident conditions that are beyond the design basis accidents:
>
> - control of the reactivity;
> - removal of heat from the core; and
> - confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases"

Because ESS is not a nuclear facility, these safety functions must be adapted to fit its circumstances. A spallation source neither creates the reactivity threat posed by a fission reactor nor has the same level of decay heat arising from a fission process. The fundamental safety functions in a spallation source are: stopping the spallation process (by stopping the proton beam); removal of afterheat from the target; and confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases. There is no need for active cooling of the helium-cooled tungsten material of the target after shut down of the proton beam [690]. However, active cooling of the target is required during proton beam on the target. While the design of the complete ESS safety programme is an ongoing effort, progressing in an integrated way with the design of the entire facility, the outlines of its basic principles and functions have been established.

Stopping the proton beam

The proton beam will be stopped in the case of any of the following events:

- Loss of target wheel rotation (to avoid compromising the first target confinement barrier)
- Loss of active cooling of the target material on the target wheel (to avoid compromising the first target confinement barrier)
- Loss of cooling of the moderator hydrogen (to avoid an uncontrolled pressure rise that could harm the first and second target confinement barriers)
- Loss of cooling of the pre-moderator water (to avoid an uncontrolled pressure rise that could harm the first and second target confinement barriers)
- Loss of cooling of the reflector (to avoid compromising the first and second target confinement barriers as well as the first confinement barrier of the reflector)
- Loss of cooling of the proton beam window (to avoid compromising the first PBW confinement barrier)
- Loss of vacuum in the accelerator tub (to avoid compromising the accelerator confinement barrier as well as protection of the machine)

The beam will also be stopped (for personnel protection) in the case of: personnel entrance into the target rooms above the monolith; personnel entrance into the accelerator tunnel; or personnel presence in the neutron instruments if there is no appropriate shutter in the line of sight if the personnel, or if an installed shutter fails to close. Abnormal beam steering can also lead to the loss of vacuum in the accelerator, which also turns the beam off. Several levels of safeguards will protect against personnel exposure within the neutron instruments. The high-radiation environment of the instrument will be searched and closed off before the shutter is opened. However, if a person is accidentally locked inside one of the neutron instruments despite these precautions, he or she will be able to trip the proton beam. In addition, an emergency switch will shut down the beam in case equipment malfunction leads to an unsolicited shutter opening. The uncontrolled release of high beam power can lead to serious damage and/or long repair times of the accelerator, the target station and neutron instruments. It is therefore crucial to maximise the operational efficiency of the facility by avoiding accidents. But also any interruptions of operations due to repair and/or maintenance work should be limited to a shortest time possible.

Figure 5.4 shows the relation between the main safety and protection systems at the ESS facility: the target safety system (TSS), the personnel protection system (PPS) and the machine protection system (MPS). The TSS addresses the actions required to operate the target station in accordance with the Swedish nuclear regulatory guidelines, and must fulfil the highest reliability demands. It covers the target station systems, the A2T (Accelerator to Target Station) section, and the intersection between target and neutron instruments. The TSS interacts with the accelerator, mainly to request a machine shutdown (switch off of the proton beam). The PPS and MPS will be designed for the protection of personnel and machine equipment throughout the conventional facilities, the accelerator, the target station and the neutron instruments. The reliability demands for the PPS are higher than those for the MPS. Details on the MPS and PPS are described in Chapter 5. Both MPS and PPS are under the responsibility of ICS.

Cooling systems, removal of afterheat and confinement of the radioactive inventory

Cooling systems for the following components must be operational for a safe performance of the facility: the target material in the target wheel and its confinement; the hydrogen moderator; the water pre-moderator; the reflector; the proton beam window; and the monolith shielding. Controlled ventilation of the following components is required for the mitigation and/or reduction of releases of radioactive substances to the environment: the target monolith; the target station connection cells; the target station building; the target station active cell; the accelerator tunnel; and the waste treatment building. Confinement of the radioactive inventory will to be controlled via the leak tightness of the first barrier (the target wheel shroud), and the second barrier (the monolith lining). Controlled pressure relief will be operational for the following cooling systems: the target wheel; the moderator (safety valve outside the monolith); the pre-moderator (safety valve outside the monolith); and the proton beam window. Controlled pressure relief will also be provided for the monolith in case of a moderator fire, explosion, or similar event.

11.3.2 Safety systems

Redundancy and diversity in active safety systems provide multiple levels of protection for personnel, the general public, and the environment. The following safety systems have been identified:

- Target safety system
- Personnel protection system,
- Target wheel cooling system,
- Target moderator cooling system,
- Target pre-moderator cooling system,
- Target reflector cooling system
- Target proton beam window cooling system
- Target wheel confinement system
- Target monolith confinement ventilation system
- Target building confinement ventilation system
- Active cells ventilation system
- Accelerator tunnel ventilation system
- Target monolith pressure relief system
- Target moderator pressure relief system
- Target pre-moderator pressure relief system
- Target proton beam window pressure relief system
- Target component handling system

Safety classification of facility systems

There are standards that deal with safety classification of systems and components for nuclear power plants. Safety classification is based on event classes with adopted maximum environmental impact that govern reliability requirements for different systems. A similar approach can be applied for ESS but it is not relevant to talk about breakdowns in the same way as in a nuclear fission reactor. However, one can determine which systems and components that are most important to prevent the release to the environment of radioactive nuclides during an accident and those essential for fulfilment of a safe operation of ESS. For ESS one safety class is suggested with the criteria given below. The following systems, structures and components are defined as radiation safety classified:

- System that has a confinement barrier function.
- Control system that provides information on safety related process parameters and the ability to control safety features.

- System for mitigating release of radioactivity to the environment.
- Monitoring system for monitoring of radioactive emissions during normal operation and accidents.
- Systems for protection of confinement barriers.
- Systems for the supply of power and media to the system defined as safety related.
- Structures that prevent the spread of contamination within the facility.
- Structures that carry static loads and protects safety related systems.
- Fire mitigation systems for protection of safety related systems.

Some external systems that are not in this list – such as cranes – could compromise these classified safety systems. The risk could come from pressurised components, accumulated heat, potential chemical reactivity, or mass, (e.g. in case of an earthquake). Such components must be secured if they are in the vicinity of classified components, or they can simply be eliminated.

11.4 Conventional safety

The radiation safety question is important both for the public as well as for the ESS employees. The conventional safety is mainly an occupational safety issue for the ESS employees and the visiting scientists. For ESS construction the main focus will be on: fire safety; hydrogen; cryogenic safety; pressure vessels; electrical safety; chemical handling; and heights and heavy loads.

Fire safety

Prevention of fire is essential especially in high-energy physics facilities as ESS. A typical fire can arise from electrical cabinets, cables and high-voltage equipment. Other sources must also be considered in the analysis. The need for local fire fighting capabilities at ESS has to be analysed in more detail. At present no on-site local fire brigade is foreseen. A fire in the accelerator, target, instrument buildings and waste building may give rise to release of radioactive gases.

Hydrogen

Hydrogen will be used as ion source of the accelerator and as a moderator in the target monolith. The handling and use of hydrogen in the accelerator will be done according to existing regulations. The main hazard of handling and operating with hydrogen is the risk of explosion. Hence, the system will be designed to be intrinsically safe. Hydrogen has a low ignition point and therefore it is vital to remove or limit all possible ignition sources, e.g. electrical connections. The assessments of radionuclide inventory in the accelerator do not indicate that this will be of any major radiological risk. Within the target monolith there will be two circuits of hydrogen at 20 K and 1.5 MPa, which will be cooled by cryogenic helium. Empty rooms within the monolith will be filled with helium, which will reduce the risk of hydrogen explosion within the target. Further analyses of the potential risk have to be evaluated.

Cryogenics

The use of cryogenics liquids and evacuated vessels constitute a potential explosion hazard and risk of suffocation. Oxygen deficiency hazards must be considered in every space where cryogenics are present. A complete risk analysis will qualify the zone of operation. Experience and construction guidelines and regulations from existing accelerator laboratories will be used. Adequate ventilation and expansion volumes will be considered. Cryogenic safety will also be important for the safety at the instruments where liquefied nitrogen and helium will be used for experiments.

Pressure vessels

Apart from the cryogenic safety, ordinary pressure vessels regulations apply as any normal industrial activity. Pressure vessels or pressurised systems containing water will or may occur in the heat recycling systems and the cooling systems.

Electrical safety

Electrical safety is of vital importance, especially in the klystron gallery where several high-voltage components will be installed. Swedish regulations specifically give the distance between high-voltage equipment if to perform maintenance during operation.

Chemical handling

At the laboratories and at the instruments, safe handling of chemicals will be important. All chemicals that are handled within ESS are under restriction of REACH [691], the European legislation for handling of chemicals. The chemicals, which are planned to be used at ESS must be registered in a database, updated by ESS and containing safety fact sheets for handling of the individual chemicals.

Height and heavy loads

An important part for the occupational safety will be preventive measures regarding heights and handling of heavy loads. Specific regulations apply for the construction of cranes and lifting devices but also the planning of how the heavy load will be internally transported (lifting zones) will be done from a safety point of view. Work places and/or work task involving high heights will be analysed, estimated from a point of risks and followed by mitigating actions or procedures.

11.5 Security

The security of ESS will be designed to meet the basic in-house security rules and fulfilment of regulatory requirements as well as the need from the users and personnel to work in an open and friendly atmosphere. Apart from the obvious in-house security rules in preventing stealth and protection of equipment, the security requirements will be treated and integrated together with the safety requirements. Especially the zoning of the facility will be integrated taking into account radiation safety, fire safety and security. Systems for entry and zoning permissions will be designed and maybe fully integrated with the personal protection system described in Section 5.2.3.

Bibliography

[1] E. H. Lehmann and D. Mannes. 'Wood investigations by means of radiation transmission techniques.' *Journal of Cultural Heritage*, 13(3, Supplement):S35–S43, 2012. ISSN 1296-2074. doi:10.1016/j.culher.2012.03.017. Wood Science for Conservation.

[2] C. Castelnovo, R. Moessner, and S. L. Sondhi. 'Magnetic monopoles in spin ice.' *Nature*, 451:42–45, 2008.

[3] S. Mühlbauer et al. 'Skyrmion lattice in a chiral magnet.' *Science*, 323(5916), 2009.

[4] D. Butler. 'Europe is warned of a 'neutron drought'...' *Nature*, 379:284, 1996.

[5] D. Butler. '...and warns of need for more neutron sources.' *Nature*, 396:8, 1998.

[6] D. Richter and T. Springer. 'A twenty years forward look at neutron scattering facilities in the OECD countries and Russia.' Technical report, European Science Foundation, Organisation for Economic Co-operation and Development Megascience Forum, 1998.

[7] European Neutron Scattering Association (ENSA). *Survey of the Neutron Scattering Community and Facilities in Europe*, 1998.

[8] European Science Foundation (ESF) and European Neutron Scattering Association(ENSA). *Survey of the Neutron Scattering Community in Europe*, 2005.

[9] F. H. Bohn et al. 'European source of science.' In *The ESS Project*, volume 1. European Spallation Source, May 2002.

[10] D. Richter. 'New science and technology for the 21st century.' In *The ESS Project*, volume 2. European Spallation Source, May 2002.

[11] F. H. Bohn et al. 'Technical report.' In *The ESS Project*, volume 3. European Spallation Source, May 2002.

[12] G. S. Bauer et al. 'Technical report status 2003.' In *The ESS Project*, volume 3 Update. European Spallation Source, Dec 2003.

[13] 'Instruments and user support.' In K. Clausen et al., editors, *The ESS Project*, volume 4. European Spallation Source, May 2002.

[14] European Strategy Forum on Research Infrastructures. *Strategy Report on Research Infrastructures - Roadmap 2010*. Luxembourg, Publications Office of the European Union, 2011. ISBN: 978-92-79-16828-4.

[15] 'ESS Science Symposia.' http://www.europeanspallationsource.se/ess-science-symposia, last accessed March 24 2013.

[16] Editors E. Janod, F. Leclercq-Hugeux, H. Mutka, J. Teixeira. 'Neutrons, sciences and perspectives.' *The European Physics Journal Special Topics*, 213, 2012.

[17] Komitee Forschung mit Neutronen. 'Perspectives of neutron research in Germany.' http://sni-portal.uni-kiel.de/kfn/kfn/SP11/Perspektiven_der_Neutronenforschung_in_Deutschland_2011-engl.pdf, last accessed March 25 2013.

[18] H. Abele. 'The neutron. Its properties and basic interactions.' *Progress in Particle and Nuclear Physics*, 60(1):1–81, 2008.

[19] S. Profumo, M. J. Ramsey-Musolf, and S. Tulin. 'Supersymmetric contributions to weak decay correlation coefficients.' *Physical Review D*, 75, 2007.

[20] K. H. Lee, P. E. Schwenn, A. R. G. Smith, et al. 'Morphology of all-solution-processed "bilayer" organic solar cells.' *Advanced Materials*, 23(6):766–770, 2011. ISSN 1521-4095. doi:10.1002/adma.201003545.

[21] S. Schorr. 'The crystal structure of kesterite type compounds: A neutron and X-ray diffraction study.' *Solar Energy Materials and Solar Cells*, 95(6):1482–1488, 2011. ISSN 0927-0248. doi:10.1016/j.solmat.2011.01.002. Special Issue: Thin film and nanostructured solar cells.

[22] A. J. Parnell, A. D. F. Dunbar, A. J. Pearson, et al. 'Depletion of PCBM at the cathode interface in P3HT/PCBM thin films as quantified via neutron reflectivity measurements.' *Advanced Materials*, 22(22):2444–2447, 2010. ISSN 1521-4095. doi:10.1002/adma.200903971.

[23] S.-I. Nishimura, G. Kobayashi, K. Ohoyama, et al. 'Experimental visualization of lithium diffusion in Li_xFePO_4.' *Nature Materials*, 7(9):707–711, 2008. ISSN 14761122.

[24] A. Magraso, J. M. Polfus, C. Frontera, et al. 'Complete structural model for lanthanum tungstate: A chemically stable high temperature proton conductor by means of intrinsic defects.' *Journal of Materials Chemistry*, 22:1762–1764, 2012. doi:10.1039/C2JM14981H.

[25] G. Gebel, S. Lyonnard, H. Mendil-Jakani, et al. 'The kinetics of water sorption in Nafion membranes: A small-angle neutron scattering study.' *Journal of Physics: Condensed Matter*, 23(23):234107, 2011.

[26] V. Keppens, D. Mandrus, B. C. Sales, et al. 'Localized vibrational modes in metallic solids.' *Nature*, 395(6705):876–878, 1998.

[27] Y. Yan, I. Telepeni, S. Yang, et al. 'Metal-organic polyhedral frameworks: High H2 adsorption capacities and neutron powder diffraction studies.' *Journal of the American Chemical Society*, 132(12):4092–4094, 2010. doi:10.1021/ja1001407. PMID: 20199070.

[28] C. M. Brown, Y. Liu, T. Yildirim, et al. 'Hydrogen adsorption in HKUST-1: A combined inelastic neutron scattering and first-principles study.' *Nanotechnology*, 20(20):204025, 2009.

[29] C. R. Clarkson, M. Freeman, L. He, et al. 'Characterization of tight gas reservoir pore structure using USANS/SANS and gas adsorption analysis.' *Fuel*, 95(0):371–385, 2012.

[30] Y. B. Melnichenko, L. He, R. Sakurovs, et al. 'Accessibility of pores in coal to methane and carbon dioxide.' *Fuel*, 91(1):200–208, 2012.

[31] S. Yang, J. Sun, A. J. Ramirez-Cuesta, et al. 'Selectivity and direct visualization of carbon dioxide and sulfur dioxide in a decorated porous host.' *Nature Chemistry*, 4(11):887–894, 2012.

[32] A. E. Whitten et al. 'Cardiac myosin-binding protein C decorates F-actin: Implications for cardiac function.' In *Proceedings of the National Academy of Sciences*, volume 105, pages 18360–18365. 2008.

[33] M. P. Christie, A. E. Whitten, G. J. King, et al. 'Low-resolution solution structures of Munc18:Syntaxin protein complexes indicate an open binding mode driven by the Syntaxin N-peptide.' *Proceedings of the National Academy of Sciences*, 109(25):9816–9821, Jun 2012. ISSN 1091-6490 (Electronic); 0027-8424 (Linking). doi:10.1073/pnas.1116975109.

[34] A. M. Hofmann, F. Wurm, E. Hühn, et al. 'Hyperbranched polyglycerol-based lipids via oxyanionic polymerization: Toward multifunctional stealth liposomes.' *Biomacromolecules*, 11(3):568–574, 2010. doi:10.1021/bm901123j. PMID: 20121134.

[35] S. V. Ghugare, E. Chiessi, B. Cerroni, et al. 'Biodegradable dextran based microgels: A study on network associated water diffusion and enzymatic degradation.' *Soft Matter*, 8(8):2494–2502, 2012.

[36] C. Sanson, O. Diou, J. Thévenot, et al. 'Doxorubicin loaded magnetic polymersomes: Theranostic nanocarriers for MR imaging and magneto-chemotherapy.' *ACS Nano*, 5(2):1122–1140, 2011. doi: 10.1021/nn102762f.

[37] K. Wood et al. 'Coupling of protein and hydration-water dynamics in biological membranes.' In *Proceedings of the National Academy of Sciences*, volume 104, pages 18049–18054. 2007.

[38] J. Pieper et al. 'Transient protein softening during the working cycle of a molecular machine.' *Physical Review Letters*, 100:228103, 2008.

[39] S. E. Oswald et al. 'Quantitative imaging of infiltration, root growth, and root water uptake via neutron radiography.' *Vadose Zone Journal*, 7(3):1035–1047, 2008.

[40] D. R. Lee et al. 'Polarized neutron scattering from ordered magnetic domains on a mesoscopic permalloy antidot array.' *Applied Physics Letters*, 82, 2003.

[41] B. Van de Wiele, A. Manzin, A. Vansteenkiste, et al. 'A micromagnetic study of the reversal mechanism in permalloy antidot arrays.' *Journal of Applied Physics*, 111(5):053915, 2012.

[42] D. Argyriou. 'ESS preliminary operations project specification.' Internal Document ESS-0001132, European Spallation Source, 28 Nov 2012.

[43] B. Lonetti, M. Camargo, J. Stellbrink, et al. 'Ultrasoft colloid-polymer mixtures: Structure and phase diagram.' *Physical Review Letters*, 106(22):228301, 2011.

[44] J. Gummel, M. Sztucki, T. Narayanan, et al. 'Concentration dependent pathways in spontaneous self-assembly of unilamellar vesicles.' *Soft Matter*, 7(12):5731–5738, 2011.

[45] K. Bressel, M. Muthig, S. Prévost, et al. 'Mesodynamics: Watching vesicle formation in situ by small-angle neutron scattering.' *Colloid & Polymer Science*, 288(8):827–840, 2010.

[46] A. P. R. Eberle and L. Porcar. 'Flow-SANS and Rheo-SANS applied to soft matter.' *Current Opinion in Colloid and Interface Science*, 17(1):33–43, 2012.

[47] T. C. B. McLeish, N. Clarke, E. de Luca, et al. 'Neutron flow-mapping: Multiscale modelling opens a new experimental window.' *Soft Matter*, 5(22):4426–4432, 2009.

[48] R. S. Graham, J. Bent, N. Clarke, et al. 'The long-chain dynamics in a model homopolymer blend under strong flow: Small-angle neutron scattering and theory.' *Soft Matter*, 5(12):2383–2389, 2009.

[49] J. Penfold and I. Tucker. 'Flow-induced effects in mixed surfactant mesophases.' *The Journal of Physical Chemistry B*, 111(32):9496–9503, 2007.

[50] D. J. Waters, K. Engberg, R. Parke-Houben, et al. 'Structure and mechanism of strength enhancement in interpenetrating polymer network hydrogels.' *Macromolecules*, 44(14):5776–5787, 2011.

[51] H.-G. Peng, M. Tyagi, K. A. Page, et al. 'Inelastic neutron scattering on polymer electrolytes for lithium-ion batteries.' In *Polymers for Energy Storage and Delivery: Polyelectrolytes for Batteries and Fuel Cells*, volume 1096 of *ACS Symposium Series*, chapter 5, pages 67–90. American Chemical Society, 2012.

[52] F. Barroso-Bujans, F. Fernandez-Alonso, J. A. Pomposo, et al. 'Macromolecular structure and vibrational dynamics of confined poly(ethylene oxide): From subnanometer 2d-intercalation into graphite oxide to surface adsorption onto graphene sheets.' *ACS Macro Letters*, 1(5):550–554, 2012.

[53] M. Laurati, P. Sotta, D. R. Long, et al. 'Dynamics of water absorbed in polyamides.' *Macromolecules*, 45(3):1676–1687, 2012.

[54] A. R. G. Smith, K. H. Lee, A. Nelson, et al. 'Diffusion - The hidden menace in organic optoelectronic devices.' *Advanced Materials*, 24(6), Dec 2011.

[55] H. Cavaye, P. E. Shaw, A. R. G. Smith, et al. 'Solid state dendrimer sensors: Effect of dendrimer dimensionality on detection and sequestration of 2,4-dinitrotoluene.' *The Journal of Physical Chemistry C*, 115(37):18366–18371, 2011. doi:10.1021/jp205586s.

[56] A. Angus-Smyth, R. A. Campbell, and C. D. Bain. 'Dynamic adsorption of weakly interacting polymer/surfactant mixtures at the air/water interface.' *Langmuir*, 28(34):12479–12492, 2012. doi: 10.1021/la301297s.

[57] W. Wang, G. Kaune, J. Perlich, et al. 'Swelling and switching kinetics of gold coated end-capped poly(N-isopropylacrylamide) thin films.' *Macromolecules*, 43(5):2444–2452, 2010.

[58] A. Zarbakhsh, J. R. P. Webster, and J. Eames. 'Structural studies of surfactants at the oil-water interface by neutron reflectometery.' *Langmuir*, 25(7):3953–3956, 2009.

[59] M. Chen, C. Dong, J. Penfold, et al. 'Adsorption of sophorolipid biosurfactants on their own and mixed with sodium dodecyl benzene sulfonate, at the air/water interface.' *Langmuir*, 27(14):8854–8866, 2011. doi:10.1021/la201660n.

[60] X. Zhang, B. C. Berry, K. G. Yager, et al. 'Surface morphology diagram for cylinder-forming block copolymer thin films.' *ACS Nano*, 2(11):2331–2341, 2008.

[61] M. S. Hellsing, V. Kapaklis, A. R. Rennie, et al. 'Crystalline order of polymer nanoparticles over large areas at solid/liquid interfaces.' *Applied Physics Letters*, 100(22):221601–4, 2012.

[62] T. Chatterjee, C. A. Mitchell, V. G. Hadjiev, et al. 'Hierarchical Polymer-Nanotube Composites.' *Advanced Materials*, 19(22):3850–3853, Oct 2007.

[63] D. W. Schaefer and R. S. Justice. 'How nano are nanocomposites?' *Macromolecules*, 40(24):8501–8517, Oct 2007.

[64] N. J. Wagner and E. D. Wetzel. 'Advanced body armor utilizing shear thickening fluids.', Jun 2007. US Patent 7,226,878.

[65] Y. S. Lee and N. J. Wagner. 'Rheological properties and small-angle neutron scattering of a shear thickening, nanoparticle dispersion at high shear rates.' *Industrial and Engineering Chemistry Research*, 45(21):7015–7024, 2006. doi:10.1021/ie0512690.

[66] P. Akcora, S. K. Kumar, V. García Sakai, et al. 'Segmental dynamics in PMMA-grafted nanoparticle composites.' *Macromolecules*, 43(19):8275–8281, 2010. doi:10.1021/ma101240j.

[67] P. Vandoolaeghe, A. R. Rennie, R. A. Campbell, et al. 'Adsorption of cubic liquid crystalline nanoparticles on model membranes.' *Soft Matter*, 4:2267–2277, 2008. doi:10.1039/B801630E.

[68] Y. Gerelli, L. Porcar, and G. Fragneto. 'Lipid rearrangement in DSPC/DMPC bilayers: A neutron reflectometry study.' *Langmuir*, 28(45):15922–15928, 2012. doi:10.1021/la303662e.

[69] A. Lopez-Rubio and E. P. Gilbert. 'Neutron scattering: A natural tool for food science and technology research.' *Trends in Food Science & Technology*, 20(11-12):576–586, 2009. ISSN 0924-2244. doi: 10.1016/j.tifs.2009.07.008.

[70] S. Z. Fisher, M. Aggarwal, A. Y. Kovalevsky, et al. 'Neutron diffraction of acetazolamide-bound human carbonic anhydrase II reveals atomic details of drug binding.' *Journal of the American Chemical Society*, 134(36):14726–14729, 2012. doi:10.1021/ja3068098.

[71] J. P. Abrahams et al. 'Structure at 2.8 Å resolution of F_1-ATPase from bovine heart mitochondria.' *Nature*, 370(6491):621–628, 1994.

[72] B. P. Pedersen et al. 'Crystal structure of the plasma membrane proton pump.' *Nature*, 450(7172):1111–1114, 2007.

[73] J. Kellosalo et al. 'The structure and catalytic cycle of a sodium-pumping pyrophosphatase.' *Science*, 337(6093):473–476, Jul 2012.

[74] E. Balog et al. 'Direct determination of vibrational density of states change on ligand binding to a protein.' *Physical Review Letters*, 93:28103, 2004.

[75] Z. Bu et al. 'Coupled protein domain motion in Taq polymerase revealed by neutron spin-echo spectroscopy.' In *Proceedings of the National Academy of Sciences*, volume 102, pages 17646–17651. 2005.

[76] O. G. Mouritsen. *Life - As a Matter of Fat: The Emerging Science of Lipidomics*. Springer, Berlin Heidelberg, 2005.

[77] K. Simons, E. Ikonen, et al. 'Functional rafts in cell membranes.' *Nature*, 387(6633):569, 1997.

[78] A. Chenal et al. 'Deciphering membrane insertion of the diphtheria toxin T domain by specular neutron reflectometry and solid-state NMR spectroscopy.' *Journal of Molecular Biology*, 391(5):872–883, 2009.

[79] A. P. Le Brun, S. A. Holt, et al. 'Monitoring the assembly of antibody-binding membrane protein arrays using polarised neutron reflection.' *European Biophysics Journal with Biophysics Letters*, 37(5):639–645, 2008.

[80] C. Johnson et al. 'Structural studies of the neural-cell-adhesion molecule by X-ray and neutron reflectivity.' *Biochemistry*, 44(2):546–554, Dec 2005.

[81] L. A. Clifton et al. 'Low resolution structure and dynamics of a colicin-receptor complex determined by neutron scattering.' *Journal of Biological Chemistry*, 287(1):337–346, Jan 2012.

[82] S. Garg et al. 'Noninvasive neutron scattering measurements reveal slower cholesterol transport in model lipid membranes.' *Biophysical Journal*, 101(2):370–377, 2011.

[83] C. K. Wang, H. P. Wacklin, and D. J. Craik. 'Cyclotides insert into lipid bilayers to form membrane pores and destabilize the membrane through hydrophobic and phosphoethanolamine-specific interactions.' *Journal of Biological Chemistry*, 288, in press 2013. doi:10.1074/jbc.M112.421198.

[84] K. C. Thompson, A. R. Rennie, M. D. King, et al. 'Reaction of a phospholipid monolayer with gas-phase ozone at the air/water interface: Measurement of surface excess and surface pressure in real time.' *Langmuir*, 26(22):17295–17303, 2010.

[85] D. Lingwood and K. Simons. 'Lipid rafts as a membrane-organizing principle.' *Science*, 327(5961):46–50, 2010.

[86] I. Vattulainen and O. G. Mouritsen. 'Diffusion in membranes.' In P. Heitjans and J. Kärger, editors, *Diffusion in Condensed Matter: Methods, Materials, Models*, pages 471–509. Springer-Verlag, Berlin, 2nd edition, 2005.

[87] C. L. Armstrong, M. A. Barrett, A. Hiess, et al. 'Effect of cholesterol on the lateral nanoscale dynamics of fluid membranes.' *European Biophysics Journal*, pages 1–13, 2012.

[88] C. L. Armstrong et al. 'Co-existence of gel and fluid lipid domains in single-component phospholipid membranes.' *Soft Matter*, 8(17):4687–4694, 2012.

[89] C. L. Armstrong et al. 'Diffusion in single supported lipid bilayers studied by quasi-elastic neutron scattering.' *Soft Matter*, 6(23):5864–5867, 2010.

[90] M. Rheinstädter. 'Dynamics of soft matter.' chapter Lipid Membrane Dynamics, pages 263–286. Springer, 2012.

[91] A. Stradner, G. Foffi, N. Dorsaz, et al. 'New insight into cataract formation: Enhanced stability through mutual attraction.' *Physical Review Letters*, 99(19):198103, 2007.

[92] F. Roosen-Runge, M. Hennig, T. Seydel, et al. 'Protein diffusion in crowded electrolyte solutions.' *Biochimica et Biophysica Acta (BBA)-Proteins & Proteomics*, 1804(1):68–75, 2010.

[93] M. Heinen, F. Zanini, F. Roosen-Runge, et al. 'Viscosity and diffusion: Crowding and salt effects in protein solutions.' *Soft Matter*, 8(5):1404–1419, 2012.

[94] V. L. Ginzburg. 'Nobel Lecture: On superconductivity and superfluidity (what I have and have not managed to do) as well as on the "physical minimum" at the beginning of the XXI century.' *Review of Modern Physics*, 76:981–998, Dec 2004. doi:10.1103/RevModPhys.76.981.

[95] J. M. Tranquada et al. 'Neutron-scattering study of the dynamical spin susceptibility in $YBa_2Cu_3O_{6.6}$.' *Physical Review B*, 46:5561–5575, 1992.

[96] L. W. Harriger, O. J. Lipscombe, C. Zhang, et al. 'Temperature dependence of the resonance and low-energy spin excitations in superconducting $FeTe_{0.6}Se_{0.4}$.' *Physical Review B*, 85:054511, Feb 2012. doi:10.1103/PhysRevB.85.054511.

[97] N. Tsyrulin, R. Viennois, E. Giannini, et al. 'Magnetic hourglass dispersion and its relation to high-temperature superconductivity in iron-tuned $Fe_{1+y}Te_{0.7}Se_{0.3}$.' *New Journal of Physics*, 14(7):073025, 2012.

[98] P. Bourges and Y. Sidis. 'Novel magnetic order in the pseudogap state of high-T_C copper oxides superconductors.' *Comptes Rendus Physique*, 12(5-6):461–479, 2011. ISSN 1631-0705. doi:10.1016/j.crhy.2011.04.006. Superconductivity of strongly correlated systems — Supraconductivité des systèmes fortement corrélés.

[99] T. Fennell et al. 'Magnetic Coulomb phase in the spin ice $Ho_2Ti_2O_7$.' *Science*, 326(5951):415–417, 2009.

[100] D. J. P. Morris, D. A. Tennant, S. A. Grigera, et al. 'Dirac strings and magnetic monopoles in the spin ice $Dy_2Ti_2O_7$.' *Science*, 326(5951):411–414, 2009. doi:10.1126/science.1178868.

[101] L. J. Chang, S. Onoda, Y. Su, et al. 'Higgs transition from a magnetic Coulomb liquid to a ferromagnet in $Yb_2Ti_2O_7$.' *Nature Communications*, 3:992, 2012.

[102] H. v. Löhneysen et al. 'Fermi-liquid instabilities at magnetic quantum phase transitions.' *Review of Modern Physics*, 79:1015, 2007.

[103] M. Enderle et al. 'Two-spinon and four-spinon continuum in a frustrated ferromagnetic spin-1/2 chain.' *Physical Review Letters*, 104:237207, 2010.

[104] C. H. Back, D. Weller, J. Heidmann, et al. 'Magnetization reversal in ultrashort magnetic field pulses.' *Physical Review Letters*, 81:3251–3254, Oct 1998. doi:10.1103/PhysRevLett.81.3251.

[105] S. J. Gamble, M. H. Burkhardt, A. Kashuba, et al. 'Electric field induced magnetic anisotropy in a ferromagnet.' *Physical Review Letters*, 102:217201, May 2009. doi:10.1103/PhysRevLett.102.217201.

[106] S. O. Mariager, F. Pressacco, G. Ingold, et al. 'Structural and magnetic dynamics of a laser induced phase transition in FeRh.' *Physical Review Letters*, 108:087201, Feb 2012. doi:10.1103/PhysRevLett.108.087201.

[107] H. Zabel and K. Theis-Bröhl. 'Polarized neutron reflectivity and scattering studies of magnetic heterostructures.' *Journal of Physics: Condensed Matter*, 2003.

[108] A. Ohtomo and H. Y. Hwang. 'A high-mobility electron gas at the $LaAlO_3/SrTiO_3$ heterointerface.' *Nature*, 427(6973):423–426, 2004.

[109] C. A. F. Vaz. 'Electric field control of magnetism in multiferroic heterostructures.' *Journal of Physics: Condensed Matter*, 24:333201, 2012.

[110] M. L. Baker, T. Guidi, S. Carretta, et al. 'Spin dynamics of molecular nanomagnets unravelled at atomic scale by four-dimensional inelastic neutron scattering.' *Nature Physics*, 8:906–911, Sep 2012.

[111] P. C. Canfield et al. 'Still alluring and hard to predict at 100.' *Nature Materials*, 10(4):259, 2011.

[112] Y. W. Long, N. Hayashi, T. Saito, et al. ‘Temperature-induced A-B intersite charge transfer in an A-site-ordered LaCu(3)Fe(4)O(12) perovskite.’ *Nature*, 458(7234):60–63, 2009.

[113] D. Kan, T. Terashima, R. Kanda, et al. ‘Blue-light emission at room temperature from Ar^+-irradiated $SrTiO_3$.’ *Nature Materials*, 4(11):816–819, 2005.

[114] M. Azuma, W. Chen, H. Seki, et al. ‘Colossal negative thermal expansion in BiNiO3 induced by intermetallic charge transfer.’ *Nature Communications*, 2:347, 2011.

[115] M. Burrard-Lucas, D. G. Free, S. J. Sedlmaier, et al. ‘Enhancement of superconducting transition temperature of FeSe by intercalation of a molecular spacer layer.’ *arXiv preprint arXiv:1203.5046*, 2012.

[116] E. H. Kisi and C. J. Howard. *Applications of Neutron Powder Diffraction*. Oxford Series on Neutron Scattering in Condensed Matter. Oxford University Press, 2008.

[117] V. M. Nield and D. A. Keen. *Diffuse Neutron Scattering from Crystalline Materials*. Oxford Series on Neutron Scattering in Condensed Matter. Oxford University Press, 2001.

[118] C. C. Wilson. *Single Crystal Neutron Diffraction from Molecular Materials*. Series on Neutron Techniques and Applications. World Scientific, 2000.

[119] T. E. Engin, A. V. Powell, R. Haynes, et al. ‘A high temperature cell for simultaneous electrical resistance and neutron diffraction measurements.’ *Review of Scientific Instruments*, 79(9), Sep 2008. ISSN 0034-6748. doi:{10.1063/1.2979011}.

[120] K. M. Ok, D. O’Hare, R. I. Smith, et al. ‘New large volume hydrothermal reaction cell for studying chemical processes under supercritical hydrothermal conditions using time-resolved in situ neutron diffraction.’ *Review of Scientific Instruments*, 80(12), Dec 2010. ISSN 0034-6748. doi:{10.1063/1.3514990}.

[121] H. Wu, W. Zhou, and T. Yildirim. ‘High-capacity methane storage in metal-organic frameworks M_2(dhtp): The important role of open metal sites.’ *Journal of the American Chemical Society*, 131(13):4995–5000, Apr 2009. ISSN 0002-7863. doi:{10.1021/ja900258t}.

[122] P. J. McGlinn, F. C. de Beer, L. P. Aldridge, et al. ‘Appraisal of a cementitious material for waste disposal: Neutron imaging studies of pore structure and sorptivity.’ *Cement and Concrete Research*, 40(8):1320–1326, Aug 2010. ISSN 0008-8846. doi:{10.1016/j.cemconres.2010.03.011}.

[123] R. I. Walton, F. Millange, R. I. Smith, et al. ‘Real time observation of the hydrothermal crystallization of barium titanate using in situ neutron powder diffraction.’ *Journal of the American Chemical Society*, 123(50):12547–12555, Dec 2001. ISSN 0002-7863. doi:{10.1021/ja011805p}.

[124] S. Takami, K.-I. Sugioka, T. Tsukada, et al. ‘Neutron radiography on tubular flow reactor for hydrothermal synthesis: In situ monitoring of mixing behavior of supercritical water and room-temperature water.’ *The Journal of Supercritical Fluids*, 63:46–51, Mar 2012. ISSN 0896-8446. doi:{10.1016/j.supflu.2011.11.010}.

[125] R. Haynes, S. T. Norberg, S. G. Eriksson, et al. ‘New high temperature gas flow cell developed at ISIS.’ *Journal of Physics Conference Series*, 251(012090), 2010. ISSN 1742-6588. doi:{10.1088/1742-6596/251/1/012090}. Proceedings of the International Conference on Neutron Scattering, ICNS2009.

[126] D. P. Riley, E. H. Kisi, and T. C. Hansen. ‘Self-propagating high-temperature synthesis of Ti_3SiC_2: II. kinetics of ultra-high-speed reactions from in situ neutron diffraction.’ *Journal of the American Ceramic Society*, 91(10):3207–3210, Oct 2008. ISSN 0002-7820. doi:{10.1111/j.1551-2916.2008.02637.x}.

[127] W. F. Kuhs and T. C. Hansen. ‘Time-resolved neutron diffraction studies with emphasis on water ices and gas hydrates.’ In H. R. Wenk, editor, *Neutron Scattering in Earth Sciences*, volume 63 of *Reviews in Mineralogy & Geochemistry*, pages 171–204. Mineralogical Society of America, 2006. ISBN 978-0-939950-75-1. doi:{10.2138/rmg.2006.63.8}.

[128] V. P. Ting, M. Schmidtmann, P. F. Henry, et al. 'The kinetics of bulk hydration of the disaccharides alpha-lactose and trehalose by in situ neutron powder diffraction.' *MedChemComm (Journal of the European Federation for Medicinal Chemistry)*, 1(5):345–348, Dec 2010. ISSN 2040-2503. doi:{10.1039/c0md00093k}.

[129] P. Albers, E. Auer, K. Ruth, et al. 'Inelastic neutron scattering investigation of the nature of surface sites occupied by hydrogen on highly dispersed platinum on commercial carbon black supports.' *Journal of Catalysis*, 196(1):174–179, 2000.

[130] D. Lennon, I. Silverwood, N. Hamilton, et al. 'Application of inelastic neutron scattering to studies of CO2 reforming of methane over alumina-supported nickel and gold-doped nickel catalysts.' *Physical Chemistry Chemical Physics*, 2012.

[131] A. G. Stepanov, A. A. Shubin, M. V. Luzgin, et al. 'Molecular dynamics of n-octane inside zeolite ZSM-5 as studied by deuterium solid-state NMR and quasi-elastic neutron scattering.' *The Journal of Physical Chemistry B*, 102(52):10860–10870, 1998.

[132] I. P. Silverwood, N. G. Hamilton, C. J. Laycock, et al. 'Quantification of surface species present on a nickel/alumina methane reforming catalyst.' *Physical Chemistry Chemical Physics*, 12(13):3102–3107, 2010. ISSN 1463-9076. doi:{10.1039/b919977b}.

[133] C. R. Gardner, C. T. Walsh, and Ö. Almarsson. 'Drugs as materials: Valuing physical form in drug discovery.' *Nature Reviews Drug Discovery*, 3(11):926–934, 2004.

[134] J. Bauer, S. Spanton, R. Henry, et al. 'Ritonavir: An extraordinary example of conformational polymorphism.' *Pharmaceutical Research*, 18(6):859–866, 2001.

[135] C. K. Leech, S. A. Barnett, K. Shankland, et al. 'Accurate molecular structures and hydrogen bonding in two polymorphs of ortho-acetamidobenzamide by single-crystal neutron diffraction.' *Acta Crystallographica Section B: Structural Science*, 62(5):926–930, 2006.

[136] M. R. Johnson, M. Prager, H. Grimm, et al. 'Methyl group dynamics in paracetamol and acetanilide: Probing the static properties of intermolecular hydrogen bonds formed by peptide groups.' *Chemical Physics*, 244(1):49–66, 1999.

[137] H. N. Bordallo, B. A. Zakharov, E. V. Boldyreva, et al. 'Application of incoherent inelastic neutron scattering in pharmaceutical analysis: Relaxation dynamics in phenacetin.' *Molecular Pharmaceutics*, 9(9):2434–2441, 2012. doi:10.1021/mp2006032.

[138] M. D. King, A. R. Rennie, K. C. Thompson, et al. 'Oxidation of oleic acid at the air-water interface and its potential effects on cloud critical supersaturations.' *Physical Chemistry Chemical Physics*, 11(35):7699–7707, 2009. ISSN 1463-9076. doi:{10.1039/b906517b}.

[139] M. D. King, A. R. Rennie, C. Pfrang, et al. 'Interaction of nitrogen dioxide (NO2) with a monolayer of oleic acid at the air-water interface - A simple proxy for atmospheric aerosol.' *Atmospheric Environment*, 44(14):1822–1825, May 2010. ISSN 1352-2310. doi:{10.1016/j.atmosenv.2010.01.031}.

[140] H. M. Kwaambwa, M. Hellsing, and A. R. Rennie. 'Adsorption of a water treatment protein from Moringa oleifera seeds to a silicon oxide surface studied by neutron reflection.' *Langmuir*, 26(6):3902–3910, Mar 2010. ISSN 0743-7463. doi:{10.1021/la9031046}.

[141] P. Westerhoff and B. Nowack. 'Searching for global descriptors of engineered nanomaterial fate and transport in the environment.' *Accounts of Chemical Research*, 2012.

[142] F. Ridi, E. Fratini, and P. Baglioni. 'Cement: A two thousand year old nano-colloid.' *Journal of Colloid and Interface Science*, 357(2):255–264, 2011.

[143] H. N. Bordallo, L. P. Aldridge, and A. Desmedt. 'Water dynamics in hardened ordinary portland cement paste or concrete: From quasielastic neutron scattering.' *The Journal of Physical Chemistry B*, 110(36):17966–17976, 2006.

[144] H. N. Bordallo, L. P. Aldridge, P. Fouquet, et al. 'Hindered water motions in hardened cement pastes investigated over broad time and length scales.' *ACS Applied Materials & Interfaces*, 1(10):2154–2162, 2009. doi:10.1021/am900332n. PMID: 20355849.

[145] N. Malikova, S. Longeville, J. M. Zanotti, et al. 'Signature of low-dimensional diffusion in complex systems.' *Physical Review Letters*, 101(26):265901, 2008.

[146] D. Pearson, A. Allen, C. G. Windsor, et al. 'An investigation on the nature of porosity in hardened cement pastes using small angle neutron scattering.' *Journal of Materials Science*, 18(2):430–438, 1983.

[147] K. D. Knudsen, J. O. Fossum, G. Helgesen, et al. 'Pore characteristics and water absorption in a synthetic smectite clay.' *Journal of Applied Crystallography*, 36(3):587–591, 2003.

[148] I. Vouldis et al. *Novel Materials for Energy Applications: A Decade of EU-Funded Research.* European Communities, 2009. ISBN 978-92-79-11379-6.

[149] M. Karlsson. 'Perspectives of neutron scattering on proton conducting oxides.' *Dalton Transactions*, 42(2):317–29, Jan 2013.

[150] I. Ahmed, C. S. Knee, M. Karlsson, et al. 'Location of deuteron sites in the proton conducting perovskite $BaZr_{0.50}In_{0.50}O_{3-y}$.' *Journal of Alloys and Compounds*, 450(1-2):103–110, Feb 2008. ISSN 0925-8388. doi:10.1016/j.jallcom.2006.11.154.

[151] J.-C. Perrin, S. Lyonnard, and F. Volino. 'Quasielastic neutron scattering study of water dynamics in hydrated nafion membranes.' *The Journal of Physical Chemistry C*, 111(8):3393–3404, 2007. doi:10.1021/jp065039q.

[152] M. Karlsson, D. Engberg, et al. 'Using neutron spin-echo to investigate proton dynamics in proton-conducting perovskites.' *Chemistry of Materials*, 22(3):740–742, 2010. doi:10.1021/cm901624v.

[153] M. Strobl, I. Manke, N. Kardjilov, et al. 'Advances in neutron radiography and tomography.' *Journal of Physics D: Applied Physics*, 42(24):243001, 2009.

[154] V. K. Peterson, Y. Liu, C. M. Brown, et al. 'Neutron powder diffraction study of D_2 sorption in Cu_3(1,3,5-benzenetricarboxylate)$_2$.' *Journal of the American Chemical Society*, 128(49):15578–15579, 2006. doi:10.1021/ja0660857.

[155] T. Yildirim and M. R. Hartman. 'Direct observation of hydrogen adsorption sites and nanocage formation in metal-organic frameworks.' *Physical Review Letters*, 95:215504, Nov 2005. doi:10.1103/PhysRevLett.95.215504.

[156] X. Lin, I. Telepeni, A. J. Blake, et al. 'High capacity hydrogen adsorption in Cu(II) tetracarboxylate framework materials: The role of pore size, ligand functionalization, and exposed metal sites.' *Journal of the American Chemical Society*, 131(6):2159–2171, 2009.

[157] J. M. Simmons, T. Yildirim, A. Hamaed, et al. 'Direct observation of activated hydrogen binding to a supported organometallic compound at room temperature.' *Chemistry-A European Journal*, 18(14):4170–4173, 2012.

[158] P. A. Georgiev, D. K. Ross, A. D. Monte, et al. 'In situ inelastic neutron scattering studies of the rotational and translational dynamics of molecular hydrogen adsorbed in single-wall carbon nanotubes (SWNTs).' *Carbon*, 43(5):895–906, 2005. ISSN 0008-6223. doi:10.1016/j.carbon.2004.11.006.

[159] A. J. Ramirez-Cuesta and P. C. H. Mitchell. 'Hydrogen adsorption in a copper ZSM5 zeolite: An inelastic neutron scattering study.' *Catalysis Today*, 120(3-4):368–373, 2007. ISSN 0920-5861. doi:10.1016/j.cattod.2006.09.024. Proceedings of the Korea Conference on Innovative Science and Technology (KCIST-2005): Frontiers in Hydrogen Storage Materials and Technology.

[160] F. Salles, D. I. Kolokolov, H. Jobic, et al. 'Adsorption and diffusion of H_2 in the MOF type systems MIL-47(V) and MIL-53(Cr): A combination of microcalorimetry and QENS experiments with molecular simulations.' *The Journal of Physical Chemistry C*, 113(18):7802–7812, 2009. doi: 10.1021/jp811190g.

[161] F. M. Mulder, B. Assfour, J. Huot, et al. 'Hydrogen in the metal-organic framework Cr MIL-53.' *The Journal of Physical Chemistry C*, 114(23):10648–10655, 2010. doi:10.1021/jp102463p.

[162] L. Ulivi, M. Celli, A. Giannasi, et al. 'Inelastic neutron scattering from hydrogen clathrate hydrates.' *Journal of Physics: Condensed Matter*, 20(10):104242, 2008.

[163] P. A. Georgiev, A. Giannasi, D. K. Ross, et al. 'Experimental Q-dependence of the rotational J=0-to-1 transition of molecular hydrogen adsorbed in single-wall carbon nanotube bundles.' *Chemical Physics*, 328(1):318–323, 2006.

[164] M. M. Murshed and W. F. Kuhs. 'Kinetic studies of methane–ethane mixed gas hydrates by neutron diffraction and Raman spectroscopy.' *The Journal of Physical Chemistry B*, 113(15):5172–5180, 2009. doi:10.1021/jp810248s. PMID: 19354304.

[165] D. K. Staykova, W. F. Kuhs, A. N. Salamatin, et al. 'Formation of porous gas hydrates from ice powders: Diffraction experiments and multistage model.' *The Journal of Physical Chemistry B*, 107(37):10299–10311, 2003. doi:10.1021/jp027787v.

[166] N. Sharma, V. K. Peterson, M. M. Elcombe, et al. 'Structural changes in a commercial lithium-ion battery during electrochemical cycling: An in situ neutron diffraction study.' *Journal of Power Sources*, 195(24):8258–8266, 2010. ISSN 0378-7753. doi:10.1016/j.jpowsour.2010.06.114.

[167] N. Kardjilov, A. Hilger, I. Manke, et al. 'Industrial applications at the new cold neutron radiography and tomography facility of the HMI.' *Nuclear Instruments and Methods A*, 542(1-3):16–21, 2005. ISSN 0168-9002. doi:10.1016/j.nima.2005.01.005. Proceedings of the Fifth International Topical Meeting on Neutron Radiography — ITMNR-5.

[168] A. Senyshyn, M. Mhlbauer, K. Nikolowski, et al. '"In-operando" neutron scattering studies on Li-ion batteries.' *Journal of Power Sources*, 203(0):126–129, 2012. ISSN 0378-7753. doi:10.1016/j.jpowsour. 2011.12.007.

[169] W. Schweika, R. P. Hermann, M. Prager, et al. 'Dumbbell rattling in thermoelectric zinc antimony.' *Physical Review Letters*, 99:125501, Sep 2007. doi:10.1103/PhysRevLett.99.125501.

[170] M. Christensen, A. B. Abrahamsen, N. B. Christensen, et al. 'Avoided crossing of rattler modes in thermoelectric materials.' *Nature Materials*, 7(10):811–815, 2008. ISSN 14761122.

[171] H.-R. Wenk. 'Application of neutron scattering in earth sciences.' *JOM (member journal of the Minerals, Metals and Materials Society)*, 64:127–137, 2012. ISSN 1047-4838. doi:10.1007/ s11837-011-0223-y.

[172] G. Grellet-Tinner, C. M. Sim, D. H. Kim, et al. 'Description of the first lithostrotian titanosaur embryo in ovo with neutron characterization and implications for lithostrotian Aptian migration and dispersion.' *Gondwana Research*, 20(2-3):621–629, 2011. ISSN 1342-937X. doi:10.1016/j.gr.2011.02. 007.

[173] A. D. Fortes, I. G. Wood, D. Grigoriev, et al. 'No evidence for large-scale proton ordering in Antarctic ice from powder neutron diffraction.' *The Journal of Chemical Physics*, 120:11376, 2004.

[174] S. Siano, W. Kockelmann, U. Bafile, et al. 'Quantitative multiphase analysis of archaeological bronzes by neutron diffraction.' *Applied Physics A: Materials Science & Processing*, 74:1139–1142, 2002.

[175] F. Grazzi, L. Bartoli, F. Civita, et al. 'Neutron diffraction characterization of Japanese artworks of Tokugawa age.' *Analytical and Bioanalytical Chemistry*, 395(7):1961–1968, 2009.

[176] F. Grazzi, L. Bartoli, F. Civita, et al. 'From Koto age to modern times: Quantitative characterization of Japanese swords with time of flight neutron diffraction.' *Journal of Analytical Atomic Spectrometry*, 26(5):1030–1039, 2011.

[177] F. Grazzi, P. Pallecchi, P. Petitti, et al. 'Non-invasive quantitative phase analysis and microstructural properties of an iron fragment retrieved in the copper-age Selvicciola Necropolis in southern Tuscia.' *Journal of Analytical Atomic Spectrometry*, 27(2):293–298, 2012.

[178] F. Salvemini, F. Grazzi, S. Peetermans, et al. 'Quantitative characterization of Japanese ancient swords through energy-resolved neutron imaging.' *Journal of Analytical Atomic Spectrometry*, 27:1494–1501, 2012. doi:10.1039/C2JA30035D.

[179] S. Paul. 'The neutron and the universe–History of a relationship.' *arXiv preprint arXiv:1205.2451*, 2012.

[180] J. Rathsman, P. Christiansen, and M. Lindroos, editors. *Proceedings from the Workshop on Neutron, Nuclear, Neutrino, Muon and Medical Physics at ESS (3N2MP)*. Lund, 2009.

[181] 'ESS Science and Scientists: Fundamental Physics Parallel Session.' Berlin, Apr 2012.

[182] V. Cirigliano, Y. Li, S. Profumo, et al. 'MSSM baryogenesis and electric dipole moments: An update on the phenomenology.' *Journal of High Energy Physics*, pages 1–23, 2010.

[183] C. A. Baker, D. D. Doyle, P. Geltenbort, et al. 'Improved experimental limit on the electric dipole moment of the neutron.' *Physical Review Letters*, 97(13):131801, 2006.

[184] V. V. Fedorov, I. A. Kuznetsov, et al. 'Neutron spin optics in noncentrosymmetric crystals as a new way for nEDM search.' *Nuclear Instruments and Methods B*, 252:131–135, 2006.

[185] P. A. Vetter et al. 'Search for oscillation of the electron-capture decay probability of ^{1}42Pm.' *Physics Letters B*, 670(3):196–199, 2008.

[186] M. Baldo-Ceolin et al. 'A new experimental limit on neutron-antineutron oscillations.' *Zeitschrift für Physik C Particles and Fields*, 63:409–416, Feb 1994.

[187] H. V. Klapdor-Kleingrothaus, E. Ma, and U. Sarkar. 'Baryon and lepton number violation with scalar bilinears.' *Modern Physics Letters A*, 17(33):2221–2228, 2002.

[188] H. Rauch and S. A. Werner. *Neutron Interferometry*. Clarendon Press, Oxford, 2000.

[189] H. Bartosik, J. Klepp, C. Schmitzer, et al. 'Experimental test of quantum contextuality in neutron interferometry.' *Physical Review Letters*, 103(040403), Jul 2009.

[190] H. Abele et al. 'Qubounce: The dynamics of ultra-cold neutrons falling in the gravity potential of the Earth.' *Nuclear Physics A*, 827:593c–595c, Aug 2009.

[191] J. S. Bell. 'On the Einstein Podolsky Rosen paradox.' *Physics*, 1(3):195, 1964.

[192] S. Kochen and E. Specker. 'The problem of hidden variables in quantum mechanics.' *Journal of Mathematics and Mechanics*, 17(1):59–87, 1967.

[193] W. Schott, T. Faestermann, P. Fierlinger, et al. 'An experiment to measure the bound-beta decay of the free neutron.' *Hyperfine Interactions*, 193(1–3):269–274, 2009. doi:10.1007/s10751-009-0011-z.

[194] L. L. Nemenov. 'Neutron decay into a hydrogen atom and an anti-neutrino.' *Soviet Journal of Nuclear Physics*, 31:115–119, 1980.

[195] L. L. Nemenov and A. A. Ovchinnikova. 'Effects of scalar and tensor interactions on the atomic decay of the neutron, n. −− >. H+n-bar.' *Soviet Journal of Nuclear Physics (Eng. Trans.)*, 31:659–660, 1980.

[196] W. Schott et al. 'An experiment for the measurement of the bound-beta decay of the free neutron.' *European Physical Journal A*, 30:603–611, 2006.

[197] J. Byrne. ‘Two-body decay of the neutron: A possible test for the existence of right-handed weak currents.’ *EPL (Europhysics Letters)*, 56(5):633, Dec 2001.

[198] H. Abele et al. ‘Is the unitarity of the quark-mixing CKM matrix violated in neutron beta-decay?’ *Physical Review Letters*, 88(211801), May 2002.

[199] K. H. Klenø, K. Lieutenant, K. H. Andersen, et al. ‘Systematic performance study of common neutron guide geometries.’ *Nuclear Instruments and Methods A*, 696:75–84, 2012.

[200] T. Kamiyama. Private communication, 2012.

[201] K. L. Krycka, R. A. Booth, C. R. Hogg, et al. ‘Core-shell magnetic morphology of structurally uniform magnetite nanoparticles.’ *Physical Review Letters*, 104:207203, May 2010. doi:10.1103/PhysRevLett.104.207203.

[202] P. Mueller-Bushbaum, E. Metwalli, J.-F. Moulin, et al. ‘Time of flight grazing incidence small angle neutron scattering.’ *European Physics Journal Special Topics*, 167:107–112, 2009. doi:10.1140/epjst/e2009-00944-5.

[203] J. Stahn, U. Filges, and T. Panzner. ‘Focusing specular neutron reflectometry for small samples.’ *The European Physical Journal - Applied Physics*, 58(01), 2012.

[204] M. Ohl, M. Monkenbusch, N. Arend, et al. ‘The spin-echo spectrometer at the Spallation Neutron Source (SNS).’ *Nuclear Instruments and Methods A*, 696:85–99, 2012. doi:http://dx.doi.org.ludwig.lub.lu.se/10.1016/j.nima.2012.08.059.

[205] P. Fouquet, G. Ehlers, B. Farago, et al. ‘The wide-angle neutron spin echo spectrometer project WASP.’ *Journal of Neutron Research*, 15:39–47, 2007. doi:10.1080/10238160601048791.

[206] M. Karlsson, P. Fouquet, I. Ahmed, et al. ‘Dopant concentration and short-range structure dependence of diffusional proton dynamics in hydrated $BaIn_xZr_{1-x}O_{3-x/2}$ (x = 0.10 and 0.50).’ *Journal of Physical Chemistry C*, 114:3292–3296, 2010. doi:10.1021/jp910224s.

[207] F. Tasset. ‘Zero field neutron polarimetry.’ *Physica B*, 157:627–630, 1989.

[208] K. Zeitelhack. ‘Report on the International Collaboration of Neutron Detectors.’ He-3 Replacements Workshop, IEEE Nuclear Science Symposia, 2011.

[209] A. Cho. ‘Helium-3 shortage could put freeze on low-temperature research.’ *Science*, 326(5954):778–779, 2009. doi:10.1126/science.326_778.

[210] D. Kramer. ‘For some, helium-3 supply picture is brightening.’ *Physics Today*, 64:20, 2011.

[211] D. A. Shea and D. Morgan. ‘The helium-3 shortage: Supply, demand, and options for Congress.’ Congressional Research Service, Library of Congress, http://digital.library.unt.edu/ark:/67531/metadc31373/, Sep 2010.

[212] T. M. Persons and G. Aloise. ‘Neutron detectors: Alternatives to using helium-3.’ United States Government Accountability Office GAO-11-753, Sep 2011.

[213] International Collaboration for the Development of Neutron Detectors. www.icnd.org, last accessed Jan 2013.

[214] *2nd International 10B BF3 Detectors Workshop*, 2012.

[215] O. Knotek, E. Lugscheider, and C. W. Siry. ‘Tribological properties of B—C thin films deposited by magnetron-sputter-ion plating method.’ *Surface and Coatings Technology*, 91(3):167–173, 1997.

[216] S. Ulrich, T. Theel, J. Schwan, et al. ‘Magnetron-sputtered superhard materials.’ *Surface and Coatings Technology*, 97(1):45–59, 1997.

[217] M. J. Zhou, S. F. Wong, C. W. Ong, et al. ‘Microstructure and mechanical properties of B_4C films deposited by ion beam sputtering.’ *Thin Solid Films*, 516(2):336–339, 2007.

[218] M. L. Wu, J. D. Kiely, T. Klemmer, et al. 'Process–property relationship of boron carbide thin films by magnetron sputtering.' *Thin Solid Films*, 449(1):120–124, 2004.

[219] S. Ulrich, H. Ehrhardt, J. Schwan, et al. 'Subplantation effect in magnetron sputtered superhard boron carbide thin films.' *Diamond and Related Materials*, 7(6):835–838, 1998.

[220] O. Tavsanoglu, O. A. Yucel, and M. Jeandin. 'A functionally graded design study for boron carbide and boron carbonitride thin films deposited by plasma-enhanced dc magnetron sputtering.' In *TMS Annual Meeting 1*, pages 279–285. 2008.

[221] C. Hoglund, J. Birch, K. Andersen, et al. 'B_4C thin films for neutron detection.' *Journal of Applied Physics*, 111(10):104908–104908, 2012.

[222] European Spallation Source AB. 'A method for producing a neutron detector component comprising a boron carbide layer for use in a neutron detecting device.' international patent application number PCT/SE2011/050891 http://patentscope.wipo.int/search/en/detail.jsf?docId=WO2013002697&recNum=287&docAn=SE2011050891&queryString=evaporators&maxRec=194643, 30 Jun 2011.

[223] H. Pedersen, C. Höglund, J. Birch, et al. 'Low temperature CVD of thin, amorphous boron-carbon films for neutron detectors.' *Chemical Vapor Deposition*, 2012.

[224] B. Alling, C. Höglund, R. Hall-Wilton, et al. 'Mixing thermodynamics of $TM_{1-x}Gd_xN$ (TM= Ti, Zr, Hf) from first principles.' *Applied Physics Letters*, 98:241911, 2011.

[225] K. Andersen, T. Bigault, J. Birch, et al. 'Multi-grid boron-10 detector for large area applications in neutron scattering science.' *arXiv preprint arXiv:1209.0566*, 2012.

[226] I. L. Langevin. 'Ionizing radiation detector.' French patent application FR no. 10/51502, 2 Mar 2010.

[227] J. Ollivier, H. Mutka, and L. Didier. 'The new cold neutron time-of-flight spectrometer IN5.' *Neutron News*, 21(2):22–25, 2010.

[228] N. J. Rhodes, A. G. Wardle, A. J. Boram, et al. 'Pixelated neutron scintillation detectors using fibre optic coded arrays.' *Nuclear Instruments and Methods A*, 392(1-3):315–318, 1997. ISSN 0168-9002. doi:10.1016/S0168-9002(97)00261-1. Position-Sensitive Detectors Conference 1996.

[229] M. L. Crow, J. P. Hodges, and R. G. Cooper. 'Shifting scintillator prototype large pixel wavelength-shifting fiber detector for the POWGEN3 powder diffractometer.' *Nuclear Instruments and Methods A*, 529(1-3):287–292, 2004. ISSN 0168-9002. doi:10.1016/j.nima.2004.04.167. Proceedings of the Joint Meeting of the International Conference on Neutron Optics (NOP2004) and the Third International Workshop on Position-Sensitive Neutron Detectors (PSND2004).

[230] Partec Ltd. (supplier). http://www.parttec.com/index.html, last accessed Jan 2013.

[231] T. Nakamura, E. M. Schooneveld, N. J. Rhodes, et al. 'A half-millimetre spatial resolution fibre-coded linear position-sensitive scintillator detector with wavelength-shifting fibre read-out for neutron detection.' *Nuclear Instruments and Methods A*, 606(3):675–680, 2009. ISSN 0168-9002. doi:10.1016/j.nima.2009.05.013.

[232] T. Nakamura, T. Kawasaki, T. Hosoya, et al. 'A large-area two-dimensional scintillator detector with a wavelength-shifting fibre readout for a time-of-flight single-crystal neutron diffractometer.' *Nuclear Instruments and Methods A*, 686(0):64–70, 2012. ISSN 0168-9002. doi:10.1016/j.nima.2012.05.038.

[233] H. O. Anger. 'Scintillation camera.' *Review of Scientific Instruments*, 29(1):27–33, 1958. doi:10.1063/1.1715998.

[234] M. Heiderich, R. Reinartz, R. Kurz, et al. 'A two-dimensional scintillation detector for small angle neutron scattering.' *Nuclear Instruments and Methods A*, 305(2):423–432, 1991. ISSN 0168-9002. doi:10.1016/0168-9002(91)90562-5.

[235] G. Kemmerling, R. Engels, N. Bussmann, et al. 'A new two-dimensional scintillation detector system for small-angle neutron scattering experiments.' *IEEE Transactions on Nuclear Science*, 48(4):1114–1117, 2001.

[236] R. Engels, R. Reinartz, and J. Schelten. 'A new 64-channel area detector for neutrons and gamma ray.' *IEEE Transactions on Nuclear Science*, 46(4):869–872, 1999.

[237] I. Stefanescu, Y. Abdullahi, J. Birch, et al. 'Development of a novel macrostructured cathode for large-area neutron detectors based on ^{10}B-containing solid converter.' *Nuclear Instruments and Methods A*, (submitted).

[238] M. Russina, F. Mezei, and F. Trouw. 'New capabilities in spectroscopy on pulsed sources: Adjustable pulse repetition rate, resolution and line shape.' In *Proceedings of the 15th Meeting of the International Collaboration on Advanced Neutron Sources, ICANS-XV*, page 349. Japan Atomic Energy Research Institute, Mar 2001.

[239] V. Antonelli et al. 'The design of a CFRP chopper disc for a time-of-flight spectrometer.' In *18th International Conference on Composite Materials*, 21.-26.8.2011. 2011.

[240] H. Stelzer. 'Quaterly report of work package K1.' Internal Report, European Spallation Source, May–Jul 2011.

[241] M. Monkenbusch. 'Multi-chopper design considerations.' Internal paper, Forschungszentrum Jülich, May 15 2011.

[242] H. Abele et al. 'Characterization of a ballistic supermirror neutron guide.' *Nuclear Instruments and Methods A*, 562:407–417, Jun 2006.

[243] C. Schanzer et al. 'Advanced geometries for ballistic guides.' *Nuclear Instruments and Methods A*, 529(1–3):63–68, Aug 2004.

[244] S. Mühlbauer et al. 'Performance of an elliptically tapered neutron guide.' *Physica B*, 385-386:1247–1249, Nov 2006.

[245] T. Hils et al. 'Focusing parabolic guide for very small samples.' *Physica B*, 350:166–168, 2004.

[246] H. Wolter. 'Spiegelsysteme streifenden einfalls als abbildende optiken fuer röntgenstrahlen.' *Annalen der Physik*, 6(10):94–114, 1952.

[247] H. Wolter. 'Verallgemeinerte schwarzschildshe spiegelsysteme streifender reflexion als optiken fuer röntgenstrahlen.' *Annalen der Physik*, 6(10):286–295, 1952.

[248] M. R. Eskildsen et al. 'Compound refractive optics for the imaging and focusing of low-energy neutrons.' *Nature*, 391:563–566, 1998.

[249] T. Oku et al. 'Development of a Fresnel lens for cold neutrons based on neutron refractive optics.' *Nuclear Instruments and Methods A*, 462(3):435–441, 2001.

[250] Paul Scherrer Institut and RISØ-DTU. 'Swiss-Danish neutron instrumentation work packages for the European Spallation Source (ESS), 2011-2014.' Internal Report, 15 Jul 2011.

[251] 'Vorhabenbeschreibung: Mitwirkung der zentren der helmholtz-gemeinschaft und der Technischen Universität München an der Design-Update-Phase der ESS.' *Jülich*, 2011. http://www.essworkshop.org/Meetings/20110111_Copenhagen/Vorhabenbeschreibung_Verbundvorhaben_%20ESS.pdf.

[252] M. . Könnecke. 'Swiss work packages for the European Spallation Source 2011-2014.' Internal Report WP5 2012.

[253] T. Gahl. 'The PSI 2nd gen motion control technology at SINQ focusing on applications in extreme environments.' In *Presentatation at Design and Engineering of Neutron Instruments (DENIM) Conference at Rutherford Laboratory*. http://www.isis.stfc.ac.uk/news-and-events/events/2012/denim-photos/technical-presentation---motion-control---gahl-t-psi13337.pdf, Sep 2012.

[254] C. Pradervand and T. Gahl. 'Motor and encoder standards for SwissFEL-applications.' PSI Elektronik Netzwerk https://controls.web.psi.ch/TWiki-4.1.2/pub/Main/StandardMotorsAndEncoders/SwissFEL_motor_and_encoder_standards_rev1-1.pdf, 2012.

[255] F. Darmann. 'Electrical engineering guidelines to be applied to neutron beam instruments and subassemblies - information for vendors - NBIP-ES-410-1032C Attachment B.', 2010.

[256] D. Beltran. *ALBA hardware guidelines.* ALBA – Computing Division, CCD-GDCTHW-ES-0001 rev 1.2, 2007.

[257] J. Destraves, T. Gahl, M. Kenzelmann, et al. '2nd gen SINQ instruments electronics.' ICANS XIX poster presentation, Grindelwald, Switzerland, Mar 2010.

[258] European Synchrotron Radiation Facility (ESRF). 'IcePAP - motion control at the ESRF.' http://www.esrf.eu/Instrumentation/DetectorsAndElectronics/icepap, last accessed Jan 2013.

[259] 'Experimental Physics and Industrial Control System.' http://www.aps.anl.gov/epics/index.php, last accessed Jan 2013.

[260] ABB. 'FRIDA - Dual arm concept robot from ABB.' http://www.abb.com/cawp/abbzh254/8657f5e05ede6ac5c1257861002c8ed2.aspx, last accessed Jan 2013.

[261] Physikalische Instrumente (PI). 'Hexapod platform and control system from Physik Instrumente (PI).' http://www.physikinstrumente.com/en/products/hexapod_tripod/hexapod_tripod_controller.php, last accessed Jan 2013.

[262] P. K. Willendrup, E. Knudsen, K. Lefmann, et al. 'McStas - A neutron ray-trace simulation package.' http://www.mcstas.org, last accessed Jan 2013.

[263] 'Mantid.' http://www.mantidproject.org, last accessed Jan 2013.

[264] P. D. Adams, P. V. Afonine, G. Bunkóczi, et al. '*PHENIX*: a comprehensive Python-based system for macromolecular structure solution.' *Acta Crystallographica Section D*, 66(2):213–221, Feb 2010. doi:10.1107/S0907444909052925. See also PHENIX homepage www.phenix-online.org.

[265] 'Single sign-on - Wikipedia, the free encyclopedia.' http://en.wikipedia.org/wiki/Single_sign-on, last accessed Jan 2013.

[266] 'PANDATA.' http://www.pan-data.eu, last accessed Jan 2013.

[267] 'The Cluster of Resarch Infrastructures for Synergies in Physics (CRISP).' http://www.crisp-fp7.eu, last accessed Jan 2013.

[268] 'eduroam.' http://www.eduroam.org, last accessed Jan 2013.

[269] M. Fromme, A. Houben, K. Lieutenant, et al. 'Virtual Instrumentation Tool for Neutron Scattering at Pulsed and Continuous Sources.' http://www.helmholtz-berlin.de/forschung/grossgeraete/neutronenstreuung/projekte/vitess/index_en.html, last accessed Jan 2013.

[270] C. L. Jacobsen and S. Skelboe. 'Data format at ESS for data acquisition and storage.' Technical Report, University of Copenhagen, 2013.

[271] S. Campbell. 'ADARA - Initial test of live streaming reduction.' http://www.youtube.com/watch?v=iGAIWoPMbL4&feature=plcp, Aug 2012. YouTube.

[272] S. Campbell. 'ADARA - Testing multiple listeners and reduction paths.' https://www.youtube.com/watch?feature=player_detailpage&v=vP4KiiwBh08, Aug 2012. YouTube.

[273] 'ROOT - A Data Analysis Framework.' http://root.cern.ch/drupal/, last accessed Jan 2013.

[274] 'NeXus scientific data format.' http://www.nexusformat.org/, last accessed Jan 2013.

[275] 'ICAT.' http://www.icatproject.org, last accessed Jan 2013.

[276] T. Otomo. Private communication, Sep 2012.

[277] P. Peterson, M. Doucet, S. Campbell, et al. 'Live analysis and high performance computing at SNS.' NOBUGS (New Opportunities for Better User Group Software) 2012 presentation, September 24-26 2012.

[278] L. Mohanambe and S. Vasudevan. 'Anionic clays containing anti-inflammatory drug molecules: Comparison of molecular dynamics simulation and measurements.' *The Journal of Physical Chemistry B*, 109(32):15651–15658, 2005. doi:10.1021/jp050480m. PMID: 16852983.

[279] P. M. Bentley and R. Cywinski. 'Evidence for a spin emulsion.' *Physical Review Letters*, 101:227202, Nov 2008. doi:10.1103/PhysRevLett.101.227202.

[280] S. L. Holm and K. Lefmann. Private communication, 2012. Niels Bohr Institute, University of Copenhagen.

[281] J. C. Smith. Private communication, 2012.

[282] R. J.-M. Pellenq, A. Kushima, R. Shahsavari, et al. 'A realistic molecular model of cement hydrates.' *Proceedings of the National Academy of Sciences*, 106(38):16102–16107, 2009. doi:10.1073/pnas.0902180106.

[283] J. J. Thomas, H. M. Jennings, and A. J. Allen. 'Relationships between composition and density of tobermorite, jennite, and nanoscale $CaOSiO_2H_2O$.' *The Journal of Physical Chemistry C*, 114(17):7594–7601, 2010. doi:10.1021/jp910733x.

[284] Y. Miao, Z. Yi, C. Cantrell, et al. 'Coupled flexibility change in cytochrome P450cam substrate binding determined by neutron scattering, NMR, and molecular dynamics simulation.' *Biophysical Journal*, 103:2167–2176, 2012.

[285] U. Ryde, L. Olsen, and K. Nilsson. 'Quantum chemical geometry optimizations in proteins using crystallographic raw data.' *Journal of Computational Chemistry*, 23(11):1058–1070, 2002. ISSN 1096-987X. doi:10.1002/jcc.10093.

[286] 'Stochfit-Stochastic Methods for Modeling X-ray and Neutron Reflectometry.' http://stochfit.sourceforge.net/, last accessed Jan 2013.

[287] S. M. Danauskas, D. Li, M. Meron, et al. 'Stochastic fitting of specular X-ray reflectivity data using *StochFit*.' *Journal of Applied Crystallography*, 41(6):1187–1193, Dec 2008. doi:10.1107/S0021889808032445.

[288] M. Björck and G. Andersson. '*GenX*: An extensible X-ray reflectivity refinement program utilizing differential evolution.' *Journal of Applied Crystallography*, 40(6):1174–1178, Dec 2007. doi:10.1107/S0021889807045086.

[289] 'GenX.' http://genx.sourceforge.net/index.html, last accessed Jan 2013.

[290] T. Perring. 'Advanced visualisation and quantification of neutron data.' NOBUGS (New Opportunities for Better User Group Software) 2012 presentation, September 2012.

[291] 'Horace.' http://horace.isis.rl.ac.uk/, last accessed Jan 2013.

[292] 'TobyFit.' http://tobyfit.isis.rl.ac.uk/, last accessed Jan 2013.

[293] 'McPhase.' http://www.mcphase.de/, last accessed Jan 2013.

[294] 'SansView.' http://danse.chem.utk.edu/sansview.html, last accessed Jan 2013.

[295] 'Atomic Simulation Environment.' https://wiki.fysik.dtu.dk/ase/, last accessed Jan 2013.

[296] G. Kresse and J. Furthmüller. 'Efficiency of ab-initio total energy calculations for metals and semiconductors using a plane-wave basis set.' *Computational Materials Science*, 6:15, 1996. See also http://www.vasp.at.

[297] G. Kresse and J. Furthmüller. 'Efficient iterative schemes for ab initio total-energy calculations using a plane-wave basis set.' *Physical Review B*, 54:11169, 1996. See also http://www.vasp.at.

[298] S. J. Plimpton. 'Fast parallel algorithms for short-range molecular dynamics.' *Journal of Computational Physics*, 117, 1995. See also http://lammps.sandia.gov/index.html.

[299] F. Plewinski. 'Description of the target station barriers and zones.' Technical Report EDMS 1253318, European Spallation Source, 2012.

[300] R. Hanslik, M. Butzek, J. Bajus, et al. 'Design of the ESS target station shielding.' Technical Report ESS 03-150-T, Forschungszentrums Jülich, 2003.

[301] European Spallation Source. *Quality management plan*, 2012. ESS-0000126.

[302] K. Jonsdottir. *Risk analysis TS full construction*. European Spallation Source, 2012. ESS-0001053.

[303] Dassault Systems. 'Dymola, multi-engineering modeling and simulation.' http://www.3ds.com/products/catia/portfolio/dymola, last accessed 14 Feb 2013.

[304] Modelica®. 'Modelica 3.2 media library user's guide.' https://modelica.org/, last accessed 14 Feb 2013.

[305] B. E. Ghidersa, M. Ionescu-Bujor, and G. Janeschitz. 'Helium Loop Karlsruhe (HELOKA): A valuable tool for testing and qualifying ITER components and their He cooling circuits.' *Fusion Engineering and Design*, 81(8–14):1471–1476, Feb 2006.

[306] B. E. Ghidersa, V. Marchese, M. Ionescu-Bujor, et al. 'HELOKA facility: Thermo-hydrodynamic model and control.' *Fusion Engineering and Design*, 83(10–12):1792–1796, Dec 2008.

[307] Karlsruhe Institute of Technology. 'Complex experiments, experimental design (KEK).' http://www.inr.kit.edu/english/64.php, last accessed 14 Feb 2013.

[308] E. Noah. 'Recommended structural material compositions for neutronic and activation studies.' Technical Report EDMS 1170528, European Spallation Source, 2011.

[309] S. A. Maloy. *AFCI Materials Handbook: Materials Data for Particle Accelerator Applications*. NM: Los Alamos National Laboratory, Los Alamos, 2006. LA-CP-06-0904, Revision 5.

[310] M. G. Horsten and M. I. de Vries. 'Tensile properties of type 316L(N) stainless steel irradiated to 10 displacements per atom.' *Journal of Nuclear Materials*, 212–215:514–518, Sep 1994.

[311] Y. Dai. 'Suitability of steels as ESS mercury target container materials.' In *Proceedings of the 13th Meeting of the International Collaboration on Advanced Neutron Sources, ICANS-XIII*. 1995. ESS-PM-4.

[312] K. Saito et al. 'Tensile properties of austenitic stainless steels irradiated at SINQ target 3.' *Journal of Nuclear Materials*, 343:253–261, 2005.

[313] S. Maloy et al. 'Shear punch testing of candidate reactor materials after irradiation in fast reactors and spallation environments.' *Journal of Nuclear Materials*, 417(1):1005–1008, 2011.

[314] J. R. Weeks et al. 'Effects of high thermal and high fast fluencies on the mechanical properties of type 6061 aluminum on the HFBR.' In *Effects of Radiation on Materials: 14th International Symposium*, volume 2, pages 441–452. American Society for Testing and Materials, Jan 1990.

[315] P. Ferguson. 'Private communication.', 2012.

[316] Y. Dai and D. Hamaguchi. 'Mechanical properties and microstructure of $AlMg_3$ irradiated in SINQ target-3.' *Journal of Nuclear Materials*, 343(1–3):184–190, Aug 2005.

[317] S. Maloy et al. 'The effect of 800 MeV proton irradiation on the mechanical properties of tungsten at room temperature and at 475 °C.' *Journal of Nuclear Materials*, 345:219, 2005.

[318] S. A. Maloy, R. S. Lillard, W. F. Sommer, et al. 'Water corrosion measurements on tungsten irradiated with high energy protons and spallation neutrons.' *Journal of Nuclear Materials*, 431:140, 2012.

[319] A. T. Nelson, J. A. O'Toole, R. A. Valicenti, et al. 'Fabrication of a tantalum-clad tungsten target for LANSCE.' *Journal of Nuclear Materials*, 431(1–3):172–184, Dec 2012.

[320] M. Matolich. 'Swelling in neutron irradiated tungsten and tungsten - 25 percent rhenium.' *Scripta Metallurgica*, 8(7):837–842, Jul 1974.

[321] E. Noah and S. Iyengar. 'Fatigue and oxidation resistance of tungsten and its alloys.' Technical Report EDMS 1218205, European Spallation Source and Lund University, 2012.

[322] L. Commin, M. Rieth, B. Dafferner, et al. 'Oxidation study of pure tungsten.' Technical Report EDMS 1165708, Karlsruhe Institute of Technology, 2012.

[323] 'ITER materials assessment report (MAR).' ITER Doc. G 74 MA 10 01-07-11 W0.3 (internal project document distributed to the ITER participants).

[324] N. Watanabe. 'Neutronics of pulsed spallation neutron sources.' *Reports on Progress in Physics*, 66(3):339, Mar 2003.

[325] T. Kai et al. 'Coupled hydrogen moderator optimization with ortho/para hydrogen ratio.' *Nuclear Instruments and Methods A*, 523(3):398–414, May 2004.

[326] T. Kai et al. 'Neutronic performance of rectangular and cylindrical coupled hydrogen moderators in wide-angle beam extraction of low-energy neutrons.' *Nuclear Instruments and Methods A*, 550(1–2):329–342, Sep 2005.

[327] F. Mezei and M. Russina. 'Neutron-optical component array for the specific spectral shaping of neutron beams or pulses.' European Patent EP1468427 B1, 2002.

[328] D. B. Pelowitz, editor. *MCNPX User's Manual, Version 2.7.0*. LA-CP-11-0438. Los Alamos National Laboratory report, Apr 2011.

[329] K. Niita, N. Matsuda, Y. Iwamoto, et al. *PHITS: Particle and Heavy Ion Transport Code System*. JAEA, Japan Atomic Energy Agency, 2010. Version 2.23, JAEA-Data/Code 2010-022.

[330] K. A. V. Riper. *Moritz User's Guide*. White Rock Science, 2000-2012 (2012).

[331] 'Monte carlo modeling interface program.' http://www.fds.org.cn/en/software/mcam_1.asp.

[332] H. Tsige-Tamirat and U. Fischer. 'CAD interface for Monte Carlo particle transport codes.' In *The Monte Carlo Method: Versatility Unbounded in a Dynamic Computing World*. American Nuclear Society, LaGrange Park, IL, April 2005.

[333] Y. Wu et al. 'CAD-based interface programs for fusion neutron transport simulation.' *Fusion Engineering and Design*, 84(7–11):1987–1992, Jun 2009.

[334] D. Filges and F. Goldenbaum. *Handbook of Spallation Research: Theory, Experiments and Applications*. Wiley-VCH, 2010.

[335] K. Batkov, F. Mezei, A. Takibayev, et al. 'Optimisation of the coupling between the ESS accelerator and target: Sensitivity to the proton beam profile.' In *20th Meeting of the The International Collaboration on Advanced Neutron Sources, ICANS XX*. Bariloche, Río Negro, Argentina, Mar 2012.

[336] Y. Nara, N. Otuka, A. Ohnishi, et al. 'Relativistic nuclear collisions at 10 AGeV energies from p+Be to Au+Au with the hadronic cascade model.' *Physical Review C*, 61(2):024901, 1999.

[337] H. W. Bertini. 'Intranuclear-cascade calculation of the secondary nucleon spectra from nucleon-nucleus interactions in the energy range 340 to 2900 MeV and comparisons with experiment.' *Physical Review*, 188(4):1711–1730, 1969.

[338] M. B. Chadwick et al. 'ENDF/B-VII.0: Next generation evaluated nuclear data library for nuclear science and technology.' *Nuclear Data Sheets*, 107(12):2931–3060, 2006.

[339] Target Division. 'Target station design update baseline.' Technical Report EDMS 1166507, European Spallation Source, 2011.

[340] Institut Laue-Langevin. 'ILL Yellow Book 2008.' http://www.ill.eu/?id=1379, 2008.

[341] F. Mezei. 'ESS target-moderator performance estimates.' Technical Report ESS-0002734, European Spallation Source, 10 May 2010.

[342] A. Konobeyev, U. Fischer, and L. Zanini. 'Advanced evaluations of displacement and gas production cross sections for chromium, iron, and nickel up to 3 GeV incident particle energy.' In *Proceedings of the 10th International Topical Meeting on Nuclear Applications and Utilization of Accelerators, AccApp11*. Knoxville, TN, US, Apr 2011.

[343] K. Lefmann and K. Nielsen. 'McStas, a general software package for neutron ray-tracing simulations.' *Neutron News*, 10(3):20–23, 1999.

[344] P. Willendrup, E. Farhi, and K. Lefmann. 'McStas 1.7: A new version of the flexible Monte Carlo neutron scattering package.' *Physica B*, 350(1–3):E735–E737, Jul 2004.

[345] E. Klinkby et al. 'Interfacing MCNPX and McStas for simulation of neutron transport.' *Nuclear Instruments and Methods A*, 700:106–110, 2013.

[346] D. Baxtor, A. Crabtree, P. Ferguson, et al. 'Spallation Neutron Source moderator overview.' In *IAEA Advanced Moderator Workshop*. Tsukuba, Japan, Nov 2011.

[347] F. X. Gallmeier, M. Wohlmuther, U. Filges, et al. 'Implementation of neutron mirror modeling capability into MCNPX and its demonstration in first applications.' *Nuclear Technology*, 168(3):768–772, Dec 2009.

[348] U. Filges et al. 'Optimization criteria for the bi-spectral moderator and their application for deriving figure of merit for the MCNP-based optimization of the European Spallation Source target-moderator-reflector system.', 2012. Paul Scherrer Institute (PSI) Internal Report.

[349] T. McManamy, M. Rennich, F. Gallmeier, et al. '3 MW solid rotating target design.' *Journal of Nuclear Materials*, 398(1–3):35–42, Mar 2010.

[350] R. Hanslik. 'Sicherheitstechnische analyse und auslegungsaspekte von abschirmungen gegen teilchenstrahlung am beispiel von spallationsanlagen im megawatt bereich.' Technische Berichte des Forschungszentrums Jülich 4225, ISSN 0944-2952, D468, Forschungszentrums Jülich, 2006.

[351] Siempelkamp. 'ESS target shielding – selection of materials, workpackage 3.1.' Technical Report, Siempelkamp Nukleartechnik GmbH, Krefeld, Germany, Dec 2003.

[352] ANSYS®. 'Academic research, release 14.0.'

[353] Y. Chen, F. Arbeiter, and G. Schlindwein. 'A comparative study of turbulance models for conjugate heat transfer to gas flow in a heated mini-channel.' *Numerical Heat Transfer*, 61(1):38–60, 2012.

[354] A. Takibayev. 'Technical note on heat deposition in tungsten target.' Technical Report EDMS 1164465, European Spallation Source, 2012.

[355] D. Ene. 'Evaluation of ESS safety concerns assuming two basic concepts of the target station.' Technical Report EDMS 1183351, European Spallation Source, 2011.

[356] C. Kharoua. 'Design calculation report. Estimation of the impact of the after heat - LOCA.' Technical Report EDMS 1164510, European Spallation Source, 2012.

[357] PLANSEE GmbH. *Catalog: Tungsten Material Properties and Applications*. http://www.plansee.com/en/Materials-Tungsten-403.htm.

[358] AFCEN (Association Française pour les régles de Conception, de construction et de surveillance en exploitation des matériels des Chaudières Electro Nucléaires). 'RCC-MR:2007 – design and construction rules for mechanical components of nuclear installations applicable to high temperature structures and to the ITER vacuum vessel.' http://www.afcen.org/, 2007.

[359] T. Lebarbé, D. Hyvert, S. Marie, et al. 'Presentation of RCC-MRx code 2010 for sodium reactors (SFR), research reactor (RR) and fusion (ITER): General overview and CEN-workshop.' *ASME Conference Proceedings*, Volume 1: Codes and Standards(PVP2011-57614):393–399, 2011.

[360] T. Shea. 'Diagnostic AIR.' ESS internal talk, 2012.

[361] P. Sabbagh. 'Cycle assumptions for fatigue analysis.' Technical Report, European Spallation Source, 2012.

[362] P. Sabbagh. 'Technical note on fatigue analysis.' Technical Report EDMS 1225592, European Spallation Source, 2012.

[363] J. Wolters, F. Albisu, G. S. Bauer, et al. 'Thermo-mechanical assessment of the disk target concept for the spallation neutron source in the Basque.' In *Proceedings of the 8th International Topical Meeting on Nuclear Applications and Utilization of Accelerators, AccApp07*. 2007.

[364] M. Berrada and J. Wolters. 'Leakage rate in labyrinth-seal systems.' Fzj-zat, Forschungszentrums Jülich, Oct 2012.

[365] M. Berrada and J. Wolters. 'Catalog: RDDM-rotatory direct drive motors.' *INA-Drives & Mechatronics*, pages 50–54, 2012.

[366] H. Haas. *Lebensdauerversuche an Kugellagern bei 120° C in Helium-Atmosphaere*. Forschungszentrums Jülich, 1986. ISSN 0366-0885.

[367] M. Berrada and J. Wolters. 'Catalog: Axial and radial roller bearings.' *INA- Rolling and plain bearings*, pages 50–54, 2012.

[368] P. Sabbagh and C. Kharoua. 'Flow blockage and its consequences on the temperature rise.' Technical Report EDMS 1225425, European Spallation Source, 2012.

[369] Y. Kasugai, K. Otsu, and T. Kai. 'Monitoring system of mercury target failure using radioactivity measurement.' *19th Meeting on Collaboration of Advanced Neutron Sources, ICANS XIX*, (398):35–42, 2010.

[370] K. Ferrell. 'Materials selection for the HFIR cold neutron source.' Technical Report ORNL/TM-99-208, Oak Ridge National Laboratory, 1999.

[371] Y. Beßler, M. Butzek, C. Tiemann, et al. 'MR design and simulation report.' Technical Report EDMS 1254214 (In preparation), Forschungszentrums Jülich, 2012.

[372] Y. Beßler, C. Tiemann, M. Butzek, et al. 'Schweißbarkeit und festigkeitsverhalten hochfester aluminiumlegierungen für den einsatz in spallations-neutronen-quellen.' Technical Report EDMS 1254224, Forschungszentrums Jülich, 2012.

[373] H. Ullmaier, A. Moslang, G. S. Bauer, et al. 'Spallation neutron for radiation damage research on nuclear materials.' In *Proceedings of the 16th Meeting of the International Collaboration on Advanced Neutron Sources*. Dusseldorf-Neuss, Germany, May 2003.

[374] M. Göhran. '2nd interface meeting between beam dump development within WU10.3 and appointed persons within the A2T group.' Technical Report EDMS 1226623, European Spallation Source, 2012.

[375] G. Schlindwein, F. Arbeiter, and J. Freund. 'Start-up phase of the HELOKA-LP low pressure helium test facility for IFMIF irradiation modules.' In *Tenth International Symposium on Fusion Nuclear Technology, ISFNT-10*. 2010.

[376] Dresser Roots®, Dresser Inc. *Catalog: Blowers, Compressors and Controls*, 2011.

[377] Siemens Turbomachinary Equipment GmbH. *Reference List of Siemens Turbomachinary Equipment GmbH (Extract)*, Nov 2011.

[378] H. Teixeira. 'Preliminary design of a hurricane system for tungsten particulate capture, from helium coolant gas stream, on the spallation reaction.' Technical Report EDMS 1192485, Advanced Cyclone Systems, SA, 2012.

[379] R. Salcedo, J. Paiva, and C. Sousa. 'Hurricane/Mechanical ReCyclone® performance at pilot-scale.' Technical Report EDMS 1192485, Advanced Cyclone Systems, SA, 2012.

[380] F. Koch and H. Bolt. 'Self passivating W-based alloys as plasma facing material for nuclear fusion.' *Physica Scripta*, page 100, Mar 2007.

[381] B. Guidersa and J. X. Zhou. 'System analysis of the helium loop for ESS target.' Unpublished, KIT, Karlsruhe Institute of Technology.

[382] F. Plewinski, P. Nilsson, and P. Sabbagh. 'Intermediate cooling circuit for target He cooling - ingress into the helium cooling target circuit – TSDU Baseline V2 (N_2).' Technical Report EDMS 1226049, European Spallation Source, 2012.

[383] P. Nilsson et al. 'Helium purification - first design estimates.' Technical Report, European Spallation Source, 2013. In preparation.

[384] M. S. Yang, R. P. Wang, Z. Y. Liu, et al. 'The helium purification system of the HTR-10.' *Nuclear Engineering and Design*, 218:163–167, 2002.

[385] A. Ciampichetti, A. Aiello, G. Coccolutoa, et al. 'The coolant purification system of the European test blanket modules: Preliminary design.' *Fusion Engineering and Design*, 85(10–12):2033–2039, Dec 2010.

[386] K. Liger, X. Lefebvre, A. Ciampichetti, et al. 'HCLL and HCPB coolant purification system: Design of the copper oxide bed.' *Fusion Engineering and Design*, 86(9–11):1859–1862, Oct 2011.

[387] M. Göhran. 'Wall thickness calculation for hot cells.' Technical Report EDMS 1223237, European Spallation Source, 2012.

[388] Nuclear Industry Guidance. *An Aid to the Design of Ventilation of Radioactive Areas, Issue 1*, Jan 2009.

[389] *Norme Francaise ISO 11933-4: Composants pour enceintes de confinement, Partie 4: Systèmes de ventilation et d'épuration tels que filtres, pièges, vannes de régulation et de sécurité, organes de contrôle et de protection*, Sep 2001.

[390] *Norme Internationale, ISO 10648-2, Enceintes de confinement, Partie 2: Classification selon leur étanchéité et méthodes de controles associées*, Dec 1994.

[391] T. Hansson and P. Jacobsson. 'General safety objectives for ESS.' Technical Report EDMS 1148774, European Spallation Source, 2011.

[392] P. Nilsson et al. 'Estimates for water cooled tungsten rods.', 2012. In preparation.

[393] F. Sordo, M. Magan, J.-P. de Vicente, et al. 'Neutronic and thermohydraulic simulations.', 2012. In preparation.

[394] A. Zhukauskas. 'Heat transfer for tubes in crossflow.' In *Advances in Heat Transfer*, volume 8, page 93. Academic Press, 1972.

[395] K. Thomsen, M. Butzek, F. Gallmeier, et al. 'Options for water cooling of a SINQ-type canneloni at high power.' In *Proceedings of the 10th International Topical Meeting on Nuclear Applications and Utilization of Accelerators, AccApp11*. Knoxville, TN, US, Apr 2011.

[396] J. Wolters et al. 'CFD simulations and thermohydraulic analysis.', 2012. In preparation.

[397] K. Thomsen, F. Heinrich, M. Butzek, et al. 'Some technical issues for a cannelloni spallation-target at high power.' *Nuclear Instruments and Methods A*, 682:42–48, Aug 2012.

[398] W. Wagner, P. Vontobel, and Y. Dai. 'Materials issues for the SINQ high-power spallation target.' *International Journal of Materials Research*, (102):1101–1105, 2011.

[399] P. Sokol. 'Design and operating experience with a beryllium target for neutron generation.' In *Proceedings of the 20th Meeting on Collaboration of Advanced Neutron Sources, ICANS XX*. 2012.

[400] R. S. Lillard, D. L. Pile, and D. P. Butt. 'The corrosion of materials in water irradiated by 800 MeV protons.' *Journal of Nuclear Materials*, 278(2–3):277–289, Apr 2000.

[401] M. Magán, S. Terrón, F. Sordo, et al. 'Union of compact accelerator-driven neutron sources (UCANS) I & II, calculations for ESS-Bilbao low energy target.' *Physics Procedia*, 26:124–131, 2012.

[402] M. Magán, S. Terrón, K. Thomsen, et al. 'Neutron performance analysis for ESS target proposal.' *Nuclear Instruments and Methods A*, 680:61–68, Jul 2012.

[403] C. Fazio et al. 'ESS 2012 LBE technical report.' Technical report, Karlsruhe Institute of Technology, 2012.

[404] E. Noah et al. 'TSCS final report on lead options for the ESS target.' Technical Report EDMS 1108740, European Spallation Source, 2010.

[405] J. Wolters. 'FP7 - neutron source ESS - investigation of upgradeability of ESS.' Technical Report GA No. 202247, European Community.

[406] C. Fazio et al. *Handbook on Lead-bismuth Eutectic Alloy and Lead Properties, Materials Compatibility, Thermal-hydraulics and Technologies.* ISBN 978-92-64-99002-9. OECD/NEA (Organisation for Economic Cooperation and Development/Nuclear Energy Association), 2007.

[407] C. Fazio et al. 'Proceedings of the international DEMETRA workshop on development and assessment of structural materials and heavy liquid metal technologies for transmutation systems.' *Journal of Nuclear Materials*, 415(3):227–459, Aug 2011.

[408] F. Stefani and G. Gerbeth. 'A contactless method for velocity reconstruction in electrically conducting fluids.' *Measurement Science and Technology*, 11:758–765, 2000.

[409] F. Stefani, G. Gerbeth, and T. Gundrum. 'Contactless inductive flow tomography.' *Physical Review E*, 70(056306), 2004.

[410] T. Wondrak, V. Galindo, G. Gerbeth, et al. 'Contactless inductive flow tomography for a model of continuous steel casting.' *Measurement Science and Technology*, 21(045402), 2010.

[411] L. Zanini et al. 'Experience from the post-test analysis of MEGAPIE.' *Journal of Nuclear Materials*, 415:367–377, 2011.

[412] 'ESS update report.' http://neutron.neutron-eu.net/n_documentation/n_reports/n_ess_reports_and_more/106, Dec 2003.

[413] J. Neuhausen. 'Environmental compliance report concerning the radioactive inventory.' EC-FP7 Project ESS-PP Deliverable D 8.2, Paul Scherrer Institute (PSI), 2010.

[414] J. Neuhausen. 'Environmental compliance report concerning the target material.' EC-FP7 Project ESS-PP Deliverable D 8.1, Paul Scherrer Institute (PSI), 2010.

[415] F. Groeschel, J. Neuhausen, A. Fuchs, et al. 'Intermediate safety report, treatment of the reference accident case.' MPR-3-GF34-001/0, Paul Scherrer Institute (PSI), 2006.

[416] E. Pitcher. 'Summary report on neutronics work in support of MEGAPIE.' Technical report, Los Alamos National Laboratory (LANL), 2002.

[417] C. Perret. 'Sicherheitsbericht zum MEGAPIE-experiment an einem target mit flussigem blei-bismuth-eutektikum in der neutronenquelle SINQ des PSI-west.' Technical report, Paul Scherrer Institute (PSI), 2002.

[418] S. Gammino et al. 'Tests of the Versatile Ion Source (VIS) for high power proton beam production.' In *19th International Workshop on ECR Ion Sources, ECRIS 2010, Proceedings*, MOPOT012. Grenoble, 2010.

[419] R. Gobin et al. 'High intensity ECR ion source (H^+, D^+, H^-) developments at CEA/Saclay.' *Review of Scientific Instruments*, 73(2):922–924, Feb 2002.

[420] L. M. Young. 'Operations of the LEDA resonantly coupled RFQ.' In *Particle Accelerator Conference, PAC 2001*, volume 1, pages 309 – 313. 2001.

[421] CEA France. 'TraceWin linac beam physics simulation package.' http://irfu.cea.fr/Sacm/logiciels/index3.php, last accessed 21 Jan 2013.

[422] ANSYS. 'Product description for Fluent simulation software.' http://www.ansys.com/Products/Simulation+Technology/Fluid+Dynamics/Fluid+Dynamics+Products/ANSYS+Fluent, last accessed 21 Jan 2013.

[423] European Spallation Source. 'ESS parameter tables.' https://bled.esss.dk/ParametersEditor/?pl=High%20Level%20Parameters, last accessed 23 Jan 2013.

[424] H. Padamsee et al. *RF Superconductivity for Accelerators.* ISBN 978-3-527-40842-9. Wiley-VCH, 2008.

[425] F. Gerigk et al. 'Choice of frequency, gradient and temperature for a superconducting proton linac.' Technical Report CERN-AB-2008-064, Cern, A&B Department, Sep 2008.

[426] M. Harrison, S. Peggs, et al. 'ESS Frequency Advisory Board report.' Internal Report ESS-doc-250-v1, European Spallation Source, Jul 2010.

[427] M. Eshraqi et al. 'Design and beam dynamics study of hybrid ESS linac.' In *IPAC2011 Proceedings*, WEPS062. 2011.

[428] A. Ponton. 'Investigations of diffferent pole tips geometries for the ESS RFQ, part 1.' ESS AD Technical Notes ESS/AD/0009, European Spallation Source, March 2011.

[429] C. K. Allen and T. P. Wangler. 'Beam halo definitions based upon moments of the particle distribution.' *Physical Review ST Accel. Beams*, 5(124202), Dec 2002.

[430] J. Lagniel. 'Halos and chaos in space-charge dominated beams.' In *EPAC96 Proceedings*, page 163. 1996.

[431] A. I. S. Holm et al. 'The high energy beam transport system for the European Spallation Source.' In *IPAC 2011 Proceedings*, THPS050. 2011.

[432] R. Duperrier et al. 'CEA Saclay codes review for high intensities linacs computations.' In *International Conference on Computational Science, ICCS 2002, Proceedings*, pages 411–418. 2002.

[433] H. Danared. 'Design of the ESS accelerator.' In *IPAC 2012 Proceedings*, THPPP071, page 3904. 2012.

[434] M. Eshraqi et al. 'End to end beam dynamics of the ESS linac.' In *IPAC 2012 Proceedings*, THPPP085, pages 3933–3935. 2012.

[435] T. P. Wangler. *RF Linear Acclerators.* Wiley-VCH, 2nd edition, 2008.

[436] M. Eshraqi, H. Danared, and R. Miyamoto. 'Beam dynamics of the ESS superconducting linac.' In *Proceedings of the 52nd ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams*, TUO3B02. 2012.

[437] D. Jeon et al. 'Formation and mitigation of halo particles in the Spallation Neutron Source linac.' *Physical Review ST Accel. Beams*, 5(094201), Sep 2002.

[438] R. Miyamoto et al. 'Numerical study of a collimation system to mitigate beam losses in the ESS linac.' In *IPAC2012 Proceedings*, MOPPC027, page 541. 2012.

[439] R. Miyamoto, I. Bustinduy, B. Cheymol, et al. 'Beam loss and collimation in the ESS linac.' In *Proceedings of the 52nd ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams*, WEO3A02. Beijing, China, 2012.

[440] M. Schuh et al. 'Influence of higher order modes on the beam stability in the high power superconducting proton linac.' *Physical Review ST Accel. Beams*, 14(051001), May 2011.

[441] S. Molloy. 'An empircal study of HOM frequencies.' Technical Report ESS-doc-92-v2, European Spallation Source, 2011.

[442] R. Ainsworth. *Thesis in preparation.* Ph.D. thesis, Royal Holloway, University of London, to be published in 2013.

[443] R. Ainsworth and S. Molloy. 'The influence of parasitic modes on beam dynamics for the European Spallation Source linac.' *Nuclear Instruments and Methods A*, 2012. ISSN 0168-9002. doi:10.1016/j.nima.2012.11.034.

[444] L. Celona et al. 'Status of the Trasco Intense Proton Source and emittance measurements.' *Review of Scientific Instruments*, 75(5):1423–1426, 2004.

[445] R. Miracoli et al. 'Note: Emittance measurements of intense pulsed proton beam for different pulse length and repetition rate.' *Review of Scientific Instruments*, 83(056109), 2012.

[446] D. Mascali et al. 'Electrostatic wave heating and possible formation of self-generated high electric fields in a magnetized plasma.' *Nuclear Instruments and Methods A*, 653-1:11–16, Oct 2011.

[447] H. P. Laqua. 'Electron Bernstein wave heating and diagnostic.' *Plasma Physics and Controlled Fusion*, 49(R1), 2007.

[448] G. Castro et al. 'Comparison between off-resonance and electron Bernstein waves heating regime in a microwave discharge ion source.' *Review of Scientific Instruments*, 83(02B501), 2012.

[449] F. F. Chen. *Introduction to the Plasma Physics and Controlled Fusion.* London Press, 2nd edition, 1986.

[450] L. Neri. 'RF system design report.' Internal Report ADU_1.6.2.1.6, European Spallation Source, 2012.

[451] B. Cheymol et al. 'First results from beam measurements at the 3 MeV test stand for CERN Linac4.' In *DIPAC 2011 Proceedings*, MOPD52, page 167. 2011.

[452] B. Cheymol et al. 'Design of the emittance meter for the 3 and 12 MeV Linac4 H^- Beam.' In *IPAC 2010 Proceedings*, MOPE052, page 1089. 2010.

[453] F. Senée et al. 'Diagnostics for high power ion beams with coherent fiber for IFMIF-EVEDA injector.' In *DIPAC 2009 Proceedings*, TUPB14, page 197. 2009.

[454] F. Grespan. 'Equivalent circuit for postcoupler stabilization in a drift tube linac.' *Physical Review ST Accel. Beams*, 15(010101), Jan 2012.

[455] A. Ismail et al. 'Space charge compensation in low energy proton beams.' In *LINAC 2004 Proceedings*, TUP15, page 324. Sep 2004.

[456] L. Tchelidze and J. Stoval. 'Estimations of residual dose rates and beam loss limits in the ESS linac.' ESS AD Technical Note ESS/AD/0039, European Spallation Source, Apr 2012.

[457] L. Tchelidze and J. Stoval. 'Estimations of residual dose rate and beam loss limits in the ESS linac.' ESS AD Technical Note ESS/AD/0026, European Spallation Source, Feb 2012.

[458] Linac4 Beam Coordination Committee - Meeting 17. Pre-chopper and 3 MeV chopper beam dynamics. CERN, 29 Jul 2010. http://indico.cern.ch/conferenceDisplay.py?confId=101517.

[459] F. Gerigk et al. 'High current linac design with examples of resonances and halo.' In *LINAC 2002 Proceedings*, page 569. Gyeongju, Korea, 2002.

[460] J. L. Munoz and I. Rodriguez. 'Multiphysics design of ESS-Bilbao linac accelerating cavities.' In *Proceedings of the COMSOL Conference 2011*. Stuttgart, 2011.

[461] O. Gonzalez et al. 'Preliminary electromagnetic design of the re-bunching RF cavities for the ESS MEBT.' ESS AD Technical Note ESS/AD/0036, European Spallation Source, Mar 2012.

[462] O. Gonzalez et al. 'Electromagnetic design of the tuning system for the re-bunching cavities of the ESS MEBT.' ESS AD Technical Note ESS/AD/0035, European Spallation Source, Mar 2012.

[463] O. Gonzalez. 'Electromagnetic design of a power coupler for the ESS MEBT.' Internal Report ADU_1.6.4.1.9, Accelerating Structures Group, ESS Bilbao, 2012.

[464] A. Ghiglino et al. 'Rebunching cavity: Preliminary design report.' ESS AD Technical Note ESS/AD/0037, European Spallation Source, Mar 2012.

[465] A. Ghiglino et al. 'Rebunching cavity: Results of first iteration with real heat generation.' ESS AD Technical Note ESS/AD/0038, European Spallation Source, Mar 2012.

[466] S. Ramberger et al. 'Drift tube linac design and prototyping for the CERN LINAC4.' In *LINAC 2008 Proceedings*, MOP049, page 184. 2008.

[467] 'COMSOL multiphysics modeling and simulation software.' http://www.comsol.com/, last accessed 22 Jan 2013.

[468] M. Lindroos et al. 'Parameter choices for the ESS linac design.' In *Proceedings of LINAC 2012*. Tel Aviv, Israel, To be published.

[469] 'CARE: Coordinated Accelerator Research in Europe for Particle Physics. Description of European collaborative research programme.' http://ec.europa.eu/research/infrastructures/pdf/care.pdf, last accessed 22 Jan 2013.

[470] 'High Intensity Pulsed Proton Injectors (HIPPI).' http://mgt-hippi.web.cern.ch/mgt-hippi/, last accessed 22 Jan 2013.

[471] C. Darve, G. Ferlin, M. Gautier, et al. 'Thermal performance measurements for a 10 meter LHC dipole prototype (cryostat thermal model 2).' LHC-Project-Note-112, CERN, 1998.

[472] X. Wang, W. Hees, and T. Köttig. 'Preliminary heat load estimates of some cryogenic components for ESS.' ESS AD Technical Note ESS/AD/0041, European Spallation Source, Jun 2012.

[473] C. Darve. 'Cryogenics for the new European Spallation Source.' In *Proceedings of the International Cryogenic Engineering Conference, ICEC23*. 2012.

[474] X. Wang, J. Weisend II, T. Koettig, et al. 'ESS linac cryogenic plant.' In *Proceedings of the International Conference on Cryogenics and Refrigeration (ICCR)*. 2013.

[475] P. Gomes, E. Blanco, et al. 'The control system for the cryogenics in the LHC tunnel.' LHC-Project-Report-1169, CERN, 2008.

[476] C. Darve, C. Balle, J. Casas-Cubillos, et al. 'Instrumentation status of the low-β magnet systems at the Large Hadron Collider (LHC).' In *Proceedings of the International Cryogenic Engineering Conference, ICEC22*. 2010.

[477] M. Jones, H. M. Durand, D. Missiaen, et al. 'Status report on the survey and alignment of the accelerators at CERN.' In *Proceedings of the 9th International Workshop on Accelerator Alignment*. Sep 2006.

[478] 'Computer Simulation Technology (CST) Microwave Studio (MWS) Simulation Software.' http://www.cst.com/Content/Products/MWS/Overview.aspx, last accessed 5 Jan 2013.

[479] G. Olry et al. 'Spoke cavity RF design.' Internal Report TR-ADU_1.4.2.2.8, Institut de Physique Nucleaire d'Orsay, 2012.

[480] P. Duchesne et al. 'Spoke cavity mechanical design.' Internal Report TR_ADU_1.4.2.2.20, Institut de Physique Nucleaire d'Orsay, 2012.

[481] N. Gandolfo et al. 'Spoke cold tuning system conceptual design.' Internal Report TR_ADU_1.4.3.3, Institut de Physique Nucleaire d'Orsay, 2012.

[482] E. Rampnoux et al. 'Spoke power coupler conceptual design.' Internal Report TR_ADU_1.4.4.4, Institut de Physique Nucleaire d'Orsay, 2012.

[483] S. Bousson et al. 'Spoke cavity developments for the EURISOL driver.' In *Proceedings of the 2006 Linear Accelerator Conference, LINAC 06*. Knoxville, USA, Aug 2006.

[484] D. Reschke et al. 'Analysis of RF results of recent nine-cell cavities at DESY.' In *SRF 2009 Proceedings*, TUPPO051, page 342. 2009.

[485] J. L. Biarrotte et al. '704 MHz superconducting cavities for a high-intensity proton accelerator.' In *1999 Workshop on RF Superconductivity, SRF99, Proceedings*, WEP005, page 384. 1999.

[486] G. Devanz et al. 'Stiffened medium beta 704 MHz elliptical cavity for a pulsed proton linac.' In *13th International Workshop on RF Superconductivity , SRF 2007, Proceedings*, TUP81. Beijing, China, 2007.

[487] S. Kim. 'Higher order mode analysis of the SNS superconducting linac.' In *Particle Accelerator Conference, PAC 2001, Proceedings*, MPPH149, page 1128. 2001.

[488] P. B. Wilson. 'High energy electron linacs: Applications to storage ring RF systems and linear colliders.' SLAC-PUB-2884 (rev.), Stanford Linear Accelerator Center, Stanford University, Stanford, California, 1991.

[489] J. Plouin et al. 'Optimized RF design of 704 MHz beta=1 cavity for pulsed proton drivers.' In *Proceedings of the 15th International Conference on RF Superconductivity, SRF 2011*, MOPO034. 2011.

[490] G. Devanz et al. 'High power pulsed tests of a beta=0.5 5-cell 704 MHz superconducting cavity.' In *15th International Conference on RF Superconductivity, SRF 2011, Proceedings*, TUPO002, page 1459. 2011.

[491] J.-P. Charrier, S. Chel, M. Desmons, et al. '704 MHz high power coupler and cavity development for high power pulsed proton linacs.' In *Proceedings of the XXIV Linear Accelerator Conference, LINAC08*, THP006. 2008.

[492] S. Mitsunobu et al. 'High power input coupler for KEKB SC cavity.' In *The 1999 Workshop on RF Superconductivity, SRF99, Proceedings*, WEP032, page 505. 1999.

[493] I. Campisi et al. 'The fundamental power coupler for the Spallation Neutron Source (SNS) superconducting cavities.' In *Particle Accelerator Conference, PAC 2001, Proceedings*, MPPH153, page 1140. 2001.

[494] M. Stirbet. 'Retrospective on fundamental power couplers for the Spallation Neutron Source at Oak Ridge.' In *XXV Linear Accelerator Conference, LINAC10, Proceedings*, THP051, page 866. 2010.

[495] G. Devanz et al. 'Cryogenic tests of a 704 MHz 1 MW power coupler.' In *IPAC 2010 Proceedings*, WEPEC001, page 2884. 2010.

[496] M. Lindroos et al. 'Upgrade strategies for high power proton linacs.' In *IPAC 2011 Proceedings*, WEPS064, page 2646. http://accelconf.web.cern.ch/accelconf/IPAC2011/papers/weps064.pdf, San Sebastian, Spain, 2011.

[497] *Electromagnetic compatibility (EMC) - Part 3-5: Limits - Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 75 A.* International Electrotechnical Commission, http://webstore.iec.ch/webstore/webstore.nsf/Artnum_PK/43153, 2009.

[498] *Electromagnetic compatibility (EMC) - Part 2-4: Environment - Compatibility levels in industrial plants for low-frequency conducted disturbances.* International Electrotechnical Commission, http://webstore.iec.ch/webstore/webstore.nsf/ArtNum_PK/28826?OpenDocument, 2002.

[499] *Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement.* International Electrotechnical Commission, http://webstore.iec.ch/webstore/webstore.nsf/Artnum_PK/43918, 2009.

[500] *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test.* International Electrotechnical Commission, http://webstore.iec.ch/webstore/webstore.nsf/Artnum_PK/977673, 2012.

[501] L. Tchelidze. 'In how long the ESS beam pulse would start melting steel/copper accelerating components?' ESS AD Technical Note ESS/AD/0031, European Spallation Source, Feb 2012.

[502] A. Nordt. 'Machine protection system requirement document.' Internal Report, European Spallation Source, 2012.

[503] H. Hassanzadegan. 'Beam current monitors requirement document.' Internal Report, European Spallation Source, June 2012.

[504] S. Peggs, editor. *ESS Conceptual Design Report.* ESS-2012-001. European Spallation Source AB, Lund, Sweden, available at https://dl.dropboxusercontent.com/u/24187786/ess/CDR_final_120206.pdf, 6 Feb 2012.

[505] H. Hassanzadegan. 'Beam position and phase monitors requirement document.' Internal Report, European Spallation Source, June 2012.

[506] 'FLUKA particle physics Monte Carlo simulation package.' http://www.fluka.org/fluka.php, last accessed 23 Jan 2013.

[507] T. Giacomini et al. 'Ionization profile monitors - IPM @ GSI.' In *Proceedings of DIPAC 2011*, TUPD51, page 419. Hamburg, Germany, 2011.

[508] C. Böhme, J. Dietrich, V. Kamerdzhiev, et al. 'Beam profile monitoring at COSY via light emitted by residual gas.' In *Proceedings of DIPAC 2009*, TUPB10, pages 185–187. Basel, Switzerland, 2009.

[509] W. Blokland, S. Aleksandrov, S. M. Cousineau, et al. 'Electron scanner for SNS ring profile measurements.' In *Proceedings of DIPAC 2009*, TUOA03, page 155. Basel, Switzerland, May 2009.

[510] N. I. Balalykin, C. Boehme, O. I. Brovko, et al. 'Development of beam position and profile monitor based on light radiation of atoms excited by the beam particles.' In *Proceedings of RuPAC XIX*, WEHP42. Dubna, Russia, 2004.

[511] T. J. McManamy, T. Shea, W. Blokland, et al. 'Spallation Neutron Source target imaging system operation.' In *Proceedings of Tenth International Topical Meeting on Nuclear Applications of Accelerators (AccApp11)*. http://www.new.ans.org/store/c_5, Apr 2011.

[512] P. D. Sheriff. *Fundamentals of N-tier Architecture.* Barnes & Noble, 2006.

[513] J. O. Hill et al. *EPICS R3.14 Channel Access Reference Manual.* 2010.

[514] M. R. Kraimer et al. *EPICS: Input / Output Controller Application Developer's Guide.* 2004.

[515] G. Trahern. 'ESS Naming Convention.' ESS/AD/0005, European Spallation Source, 2010.

[516] A. Nordt, F. Plewinski, and T. Shea. 'Operational machine states and modes.' ESS AD Technical Note ESS/AD/0044, European Spallation Source, Sep 2012.

[517] H. E. Roland and B. Moriarty. *System Safety Engineering and Management.* John Wiley and Sons, 1990.

[518] N. G. Leveson. 'A new accident model for engineering safer systems.' *Safety Science*, 42:237–270, 2004. doi:doi:10.1016/S0925-7535(03)00047-X.

[519] D. Smith and K. Simpson. *Safety Critical Systems Handbook: A Straightforward Guide to Functional Safety, IEC 61508 (2010 Edition) And Related Standards, Including Process IEC 61511, and Machinery IEC 62061 and ISO 13849.* Butterworth-Heinemann (Elsevier), Oxford, England and Burlington, MA, third edition, 2011.

[520] 'Functional safety of electrical/electronic/programmable electronic safety-related system - part 1: General requirements.' Industrial Safety Standard IEC 61508-1, first edition, International Electrotechnical Comission (IEC), 1998.

[521] 'Functional safety of electrical/electronic/programmable electronic safety-related system - part 4: Definitions and abbreviations.' Industrial Safety Standard IEC 61508-4, second edition, International Electrotechnical Comission (IEC), 2010.

[522] M. Stockner. *Beam loss calibration studies for high energy proton accelerators.* Ph.D. thesis, Vienna Technical University - Institute for Theoretical Physics, 2008.

[523] 'Definition from Wikipedia: Subharmonic.' http://en.wikipedia.org/wiki/Subharmonic, last accessed 21 Feb 2013.

[524] J. Pietarinenn. 'MRF Timing System.' Timing workshop CERN, http://www.mrf.fi/pdf/presentations/MRF.CERN.Feb2008.pdf, Feb 2008.

[525] 'EPICS Process Variable Gateway.' http://www.aps.anl.gov/epics/extensions/gateway/index.php, last accessed 21 Feb 2013.

[526] 'EPICS Channel Archiver and Archive Viewer.' http://ics-web.sns.ornl.gov/kasemir/archiver/, last accessed 21 Feb 2013.

[527] 'IRMIS: Integrated Relational Model of Installed Systems.' http://irmis.sourceforge.net/, last accessed 21 Feb 2013.

[528] A. Wallander. 'Plant system I&C architecture.' Version 2.3, ITER, 7 Feb 2011.

[529] T. Erl. *Service-Oriented Architecture: Concepts, Technology, and Design.* Prentice Hall, 2005.

[530] 'ISO/IEC 15288:2008, Systems and software engineering - System life cycle processes.', 2008.

[531] J. Galambos et al. 'XAL – The SNS application programming infrastructure.' In *Proceedings of EPAC 2004.* Lucerne, Switzerland, 2004.

[532] I. Verstovsek, K. Zagar, and T. Satogata. 'European Spallation Source control system study.' Technical Report CSL-DOC-10-53451, CosyLab, 2010.

[533] P. Lapostolle and M. Weiss. 'Formulae and procedures useful for the design of linear accelerators.' Technical Report CERN-PS-2000-001, European Organisation for Nuclear Research, (CERN - PS Division), http://cdsweb.cern.ch/record/428133/files/, last accessed 10 Apr 2013, 2010.

[534] C. K. Allen, M. Ikegami, et al. 'XAL online model enhancements for J-PARC commissioning and operation.' In *Proceedings of the 2007 Particle Accelerator Conference*, MOPAN029. Albuquerque, NM USA, available at http://accelconf.web.cern.ch/accelconf/p07/PAPERS/MOPAN029.PDF, last accessed 10 Apr 2013, 2007.

[535] 'Definition of the term "artifact" in PC Magazine's online encyclopedia.' `http://www.pcmag.com/encyclopedia_term/0,1237,t=artifact&i=37999,00.asp`, last accessed 18 Feb 2013.

[536] 'Jenkins CI home page.' `http://jenkins-ci.org/`, last accessed 19 Feb 2013.

[537] 'Apache maven project homepage.' `http://maven.apache.org/general.html`, last accessed 19 Feb 2013.

[538] 'Artifactory open source repository manager homepage.' `http://www.jfrog.com/home/v_artifactory_opensource_technology`, last accessed 19 Feb 2012.

[539] 'Mercurial SCM homepage.' `http://mercurial.selenic.com/`, last accessed 19 Feb 2013.

[540] 'JUnit software testing framework homepage.' `http://junit.sourceforge.net/`, last accessed 19 Feb 2013.

[541] 'Bugzilla home page.' `http://www.bugzilla.org/`, last accessed 21 Feb 2013.

[542] D. Gurd et al. 'Human-Machine Interface (HMI) Standard [for SNS].' `https://ics-web.sns.ornl.gov/hmi/hmiStandard.pdf`, Mar 2003.

[543] C. Rode. 'The SNS superconducting linac system.' In *Proceedings of the 2001 Particle Accelerator Conference, PAC2001*, pages 619 – 623. IEEE, 2001.

[544] T. Peterson. 'Notes about the limits of heat transport from a TESLA helium vessel with a nearly closed saturated bath of helium II.' Report 1994-18, TESLA, Hamburg, 1993.

[545] S. Van Sciver. *Helium Cryogenics.* Plenum Press, New York and London, 2012.

[546] P. Lebrun. 'Large cryogenic helium refrigeration system for the LHC.' In *Proceedings of the 3rd International Conference on Cryogenics & Refrigeration, ICCR2003*, pages 11–13. 2003.

[547] N. Ohuchi et al. 'Study of thermal radiation shields for the ILC cryomodule.' *Advances in Cryogenic Engineering*, 57A:292–936, 2012.

[548] D. Arenius et al. 'Overview and status of the 12 GeV cryogenic system upgrade at JLab.' *Advances in Cryogenic Engineering*, 55:1087–1091, 2010.

[549] M. White. 'Spallation Neutron Source (SNS).' In *Advances in Cryogenic Engineering: Proceedings of the Cryogenic Engineering Conference - CEC*, volume 613 of *AIP Conference Proceedings*, pages 15–24. 2002.

[550] T. Aso. 'Design result of the cryogenic hydrogen circulation system for 1 MW pulse spallation neutron source (JNSN) in JPARC.' In *Advances in Cryogenic Engineering: Transactions of the Cryogenic Engineering Conference - CEC*, volume 823 of *AIP Conference Proceedings*, pages 763–770. 2005.

[551] J. Weisend II et al. 'The cryogenic system for the SLAC E158 experiment.' *Advances in Cryogenic Engineering*, 47A:171–179, 2002.

[552] S. Gallimore. 'Private communication.', 2012.

[553] T. Peterson. 'Recent cryogenics activity and plans at Fermilab. Presentation at 2010 cryogenic operations workshop.' List of workshop presentations available at: `http://www.triumf.info/hosted/cryo-ops/program.html`, 2010.

[554] 'Cryogenics operations workshop.' Vancouver, BC, hosted by TRIUMF. Presentations available at `http://www.triumf.info/hosted/cryo-ops/committee.html`, 2010.

[555] R. Ruber, V. Ziemann, and T. Ekelöf. 'RF development for ESS.' Internal Memo RR/2009/02, Uppsala University, 2009.

[556] J. Knobloch et al. 'HoBiCaT – A test facility for superconducting RF systems.' In *Proceedings of the 11th Workshop on RF Superconductivity*, MOP48, page 173. DESY, 2003.

[557] P. Clay, J. Desvard, R. Duthil, et al. 'Cryogenic and electrical test cryostat for instrumented superconducting RF cavities (CHECHIA).' In P. Kittel, editor, *Advances in Cryogenic Engineering*, volume 41 of *A Cryogenic Engineering Conference Publication*, pages 905–910. Springer US, 1996.

[558] H. Saugnac et al. 'Cryogenic installation status of the "CRYHOLAB" test facility.' In *Proceedings of the 10th Workshop on RF Superconductivity*, PZ007, page 632. Tsukuba, Japan, 2001.

[559] H. Saugnac et al. 'CryHoLab, a horizontal cavity test facility: New results and development.' In *Proceedings of the 11th Workshop on RF Superconductivity*, MOP46, page 168. DESY, 2003.

[560] A. Sunesson. 'Utility requirements for test stand.' Internal Document RFS-TST-UTIL-REQ, version 1.2, European Spallation Source, Aug 2012.

[561] L. Lilje. 'XFEL: Plans for 101 cryomodules.' In *Proceedings of the 13th International Workshop on RF Superconductivity*, MO102. Beijing, China, 2007.

[562] A. Bokenstrand. 'Miljökonsekvensbeskrivning (environmental impact assessment).' ESS-0000007, submitted to Swedish regulatory authorities, European Spallation Source, 7 Mar 2012.

[563] C. Sverdrup and A. Bokenstrand. 'Teknisk beskrivning (technical description).' Submitted to Swedish regulatory authorities ESS-0000006, European Spallation Source, 7 Mar 2012.

[564] Lund Building Office (Stadsbyggnadskontoret). 'Fördjupning av översiktsplanen Brunnshög.' Lund municipal detailed land use plan and comprehensive plan for Brunnshög, 2 Mar 2012.

[565] 'Energy for sustainable science. ESS energy solution.' European Spallation Source brochure, Sep 2011.

[566] LEED. 'U.S. green building council enironmental classification system.' For more information see: http://new.usgbc.org/leed, last aqccessed 22 Feb 2013.

[567] BREEAM. 'BRE trust environmental assessment method and rating system.' For more information see: http://www.breeam.org, last accessed 22 Feb 2013.

[568] Sweden Green Building Council. 'Miljöbyggnad, environmental classification system.' For more information see: http://www.sgbc.se, 2012.

[569] B. Yndemark. 'Feasibility study – Fire safety strategy report.' ESS-0002381, European Spallation Source, 30 Oct 2012.

[570] T. Parker. 'ESS energy design report.' Technical Report ESS-0001761, European Spallation Source, 22 Jan 2013.

[571] B. Kildetoft. 'ESS building program, version 9.' Internal Document, European Spallation Source, Jan 2012.

[572] H. Norberg. 'BIM guidelines for conventional facilities and civil engineering work.' Internal Document ESS-0000340, European Spallation Source, 2011.

[573] 'Bygghandlingar 90: Del 7 redovisning av anläggning, del 8, digitala leveranser för bygg och förvaltning, utgåva 2.' See: http://www.bygghandlingar90.se/.

[574] Svensk Byggtjänst. 'BSAB 96. System och tillämpningar. Utgåva 3 (classification system).' For more information, see: http://bsab.byggtjanst.se/BSAB/Om, 2005.

[575] *CAD-lager. SB11.* Sv Byggtjänst AB, Utgåva 3, 2011. Rekommendationer för tillämpning av SS-ISO 13567.

[576] A. Lagergren. 'Östra Odarslöv 13:5 (skifte 1 och 2).' UV Rapport 2012:42, Arkeologisk utredning steg 1 2011, Dnr 421-3129-2011, Swedish National Heritage board, Riksantikvarieämbetet, 2011.

[577] A. Lagergren. 'Östra Odarslöv 13:5, ESS.' UV Rapport 2012:120, Arkeologisk utredning steg 2 2012, Dnr 421-4393-2011, Swedish National Heritage board, Riksantikvarieämbetet, 2012.

[578] Svensk Byggtjänst. *AMA Anläggning 10, Swedish edition.* Edita Västra Aros AB, Västerås, 2011.

[579] P. Jacobsson. 'ID-report – Handling of non-rad waste and chemical substances.' ESS-0000010, European Spallation Source, 2011.

[580] 'Detaljplan för Östra Odarslöv 13.5 m fl i lund.' Lunds kommun utställningshandling, planbeskrivning, 2012.

[581] L.-O. Hartzén, P. Svensson, and C. Ranelycke. 'Storm water; ID-report – Supporting document for the licensing process.' ESS-0000013 Revision 2, European Spallation Source, 24 Nov 2011.

[582] 'BVF: Förordning (1994:1215) om tekniska egenskapskrav på byggnadsverk m.m.' Svensk författningssamling SFS 1994:1215, 1994.

[583] 'PBL: Plan- och bygglag (2010:900).' Svensk författningssamling SFS 2010:900, 2010.

[584] 'Swedish Agency for Disability Policy Coordination [Myndigheten för Handikappolitisk Samordning].' See: http://www.handisam.se, last accessed 22 Feb 2013.

[585] 'Swedish Work Environment Authority [Arbetsmiljöverket].' See: http://www.av.se, last accessed 22 Feb 2013.

[586] *Protection against lightning - Part 1: General principles.* SS-EN 62305-1, 2nd edition, 2011.

[587] *Protection against lightning - Part 2: Risk management.* SS-EN 62305-2, 2nd edition, 2012.

[588] *Protection against lightning - Part 3: Physical damage to structures and life hazard.* SS-EN 62305-3, 2nd edition, 2011.

[589] *Protection against lightning - Part 4: Electrical and electronic systems within structures.* SS-EN 62305-4, 2nd edition, 2011.

[590] 'ISO 8573-1:2001 Compressed air quality standards.', 2001.

[591] *SSF 130 Utgåva 8, Regler för projektering och installation av inbrotts- och överfallslarmanläggning.* Svenska Stöldskyddsföreningen, 2012. ISBN: 9789189234574.

[592] NASA. *NASA Systems Engineering Handbook.* NASA/SP-2007-6105 Rev1. NASA, 2007.

[593] C. Haskins. *Systems Engineering Handbook.* INCOSE, 3rd edition, 2006.

[594] L. Berdén. 'Quality management policy.' Internal Document ESS-0000126 Rev1, European Spallation Source, 2012.

[595] Kvalitetsledning, SIS/TK 304. *Quality Management Systems - Requirements (ISO 9001:2008)*, 2008.

[596] R. Duperrier. 'System engineering policy.' Internal Document ESS-0000967, European Spallation Source, 2011.

[597] M. Klein Velderman. 'ESS risk management policy.' Internal Document ESS-0000111 Rev 1, European Spallation Source, 2012.

[598] T. Hansson. 'Standards, norms and guidelines recommended for the design and construction of ESS.' Internal Document ESS-0000034, Rev1, European Spallation Source, 2012.

[599] K. Forsberg et al. *Visualizing Project Management.* John Wiley & Sons Inc., 3rd edition, 2005.

[600] G. Lanfranco. 'The ESS plant breakdown structure.' Internal Document ESS-0000940, Rev1, European Spallation Source, 2012.

[601] G. Lanfranco. 'The ESS configuration management plan.' Internal Document ESS-0000254, Rev1, European Spallation Source, 2012.

[602] G. Lanfranco. 'The process flow from beam line element design to 3D virtual models at ESS.' Internal Document ESS-0000941, Rev1, European Spallation Source, 2012.

[603] G. Lanfranco. 'The site-wide coordinate system (SCS) at ESS.' Internal Document ESS-0000091, Rev1, European Spallation Source, 2012.

[604] G. Lanfranco. 'Factory and site acceptance tests.' Internal Document ESS-0000465, Rev1, European Spallation Source, 2012.

[605] P. Carlsson. 'Transition to operations plan.' Internal Document ESS-0001937, European Spallation Source, 29 Nov 2012.

[606] S. Gysin. 'ESS accelerator systems construction project specification (ACCSYS).' Internal Document ESS-0001156, European Spallation Source, 28 Nov 2012.

[607] O. Kirstein. 'Neutron scattering systems project specification.' Internal Document ESS-0000817, European Spallation Source, 28 Nov 2012.

[608] G. Trahern and M. Rescic. 'ESS specification for integrated control system, construction phase.' Internal Document ESS-0001121, European Spallation Source, 22 Nov 2012.

[609] M. Eneroth, M. Åberg, and L. Persson. 'Project specification for conventional facilities construction phase (2013 -2019).' Internal Document ESS-0002388, European Spallation Source, 21 Nov 2012.

[610] S. Henderson. 'Recent commissioning results from the Spallation Neutron Source.' In *Proceedings of the 39th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams, HB2006*, MOAP02. Tsukuba, Japan, 2006.

[611] T. Mason and N. Holtkamp. 'The Spallation Neutron Source: Operational aspects and reliability in the transition from commissioning to fully committed user operation.' Technical Report No 102000000-TR0004, Spallation Neutron Source.

[612] R. Cutler et al. 'Oak Ridge National Laboratory Spallation Neutron Source electrical systems availability and improvements.' In *Proceedings of the 2011 Particle Accelerator Conference*, TUP274. NY, USA, 2011.

[613] J. Galambos. 'Spallation Neutron Source operational experience at 1 MW.' In *Proceedings of the 46th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams, HB2010*, TUO2C01. Morshach, Switzerland, 2010.

[614] 'Report on operations.' Internal Report (draft), The Cross Functional Working Group (CFWG) European Spallation Source, Dec 2012.

[615] J. Galambos et al. 'A fault recovery system for the SNS superconducting cavity linac.' In *Proceedings of LINAC 2006*, MOP057, pages 174–176. Knoxville, Tennessee USA, 2006.

[616] L. Zanini et al. 'Experience from the post-test analysis of MEGAPIE.' *Journal of Nuclear Materials*, 415(3):367, Aug 2011.

[617] C. Carlile. 'Application for permission under the Swedish Radiation Protection Act.' ESS letter to regulatory authorities ESS-0000043, European Spallation Source, 2012.

[618] D. Ene. 'Radiation protection studies for the ESS superconducting linear accelerator.' Technical Report EDMS 1093060, European Spallation Source, 2010.

[619] Swedish Radiation Safety Authority. *The Swedish Radiation Safety Authority's regulations and general advice concerning clearance of materials, rooms, buildings and land in practices involving ionising radiation*, 2011. SSMFS 2011:2.

[620] D. Ene. 'Activation studies on ESS target concepts: Sensitivity analysis.' Technical Report EDMS 1093916, European Spallation Source, 2010.

[621] F. Gallmeier. 'CNCS beam line shielding calculations.' CNCS-05-70-DA0001-R00, SNS, USA, 2004.

[622] D. Ene. 'Assessment of the radioactive inventory in terms of the waste characterization for final disposal.' Technical Report EDMS 1259515, European Spallation Source, 2012.

[623] D. Ene. 'Proposal for the source term definitions: Normal operation nuclides break down lists.' Technical Report EDMS 1183350, European Spallation Source, 2011.

[624] D. Ene. 'Activation studies of the shielding structures for the EURISOL 4 MW target station in terms of the waste characterization for final disposal.' In *Proceedings: First International Workshop on Accelerator Radiation Induced Activation*. PSI, Switzerland, 2008.

[625] A. Boudard et al. 'New potentialities of the Liège intranuclear cascade (INCL) model for reactions induced by nucleons and light charged particles.' *Physical Review C*. Submitted 2012.

[626] A. Kelic et al. 'ABLA07 - towards a complete description of the decay channels of a nuclear system from spontaneous fission to multifragmentation.' In *Contribution to the Joint ICTP-IAEA Advanced Workshop on Model Codes for Spallation Reactions*, NDS-530, page 181. IAEA INDC, 2008.

[627] 'Nuclear data services.' Technical report, International Atomic Energy Agency IAEA, http://www-nds.iaea.org/spallations, last accessed 18 Feb 2013.

[628] A. Leprince et al. 'Excitation functions on thin ^{nat}W target from the new INCL4.6-Abla07.' Internal Report CEA-Irfu 12-61, CEA, 2012.

[629] Y. Titarenko, V. Batyaev, A. Titarenko, et al. 'Measurement and simulation of the cross sections for nuclide production in ^{56}Fe and ^{nat}Cr targets irradiated with 0.04- to 2.6-GeV protons.' *Physics of Atomic Nuclei*, 74(4):523–536, Apr 2011. doi:10.1134/S1063778811040168.

[630] R. Michel et al. 'Cross sections for the production of radionuclides by proton-induced reactions on W, Ta, Pb and Bi from thresholds up to 2.6 GeV.' *Journal of Nuclear Science and Technology*, 2(Suppl.):242, 2002.

[631] J. L. Ulmann et al. 'APT radionuclide production experiment.' Technical Report LA-UR-95-3327, Los Alamos National Laboratory, 1995.

[632] Y. Kasugai et al. 'Measurement of radioactivity induced by GeV-protons and spallation neutrons using AGS accelerator.' Research Report 2003-034, Japan Atomic Energy Research Institute, 2004.

[633] A. Leprince et al. 'Reliability and use of INCL4.6-Abla07 spallation model in the frame of European Spallation Source target design.' In *Proceedings of the 12th International Conference on Radiation Shielding, ICRS-12/17th Topical Meeting of the Radiation Protection and Shielding Division of the American Nuclear Society, RPSD-2012*. 2012.

[634] A. Konobeyev et al. 'Computational approach for evaluation of nuclear data including covariance information.' *Journal of the Korean Physical Society*, 59(2):923–926, Aug 2011.

[635] D. Ene. 'ESS radwaste streams evaluation. Basis for waste management planning.' Technical Report ESS-0001922, European Spallation Source, 2012.

[636] L. Almqvist. 'Avfallshandbok – låg- och medelaktivt avfall, version 2.0.' DokumentID 1195328, Svensk kärnbränslehantering AB (SKB), 2009.

[637] 'Classification of radioactive waste – general safety guide.' IAEA Safety Standards Series No. GSG-1, International Atomic Energy Agency, Vienna, 2009.

[638] A. Y. Konobeyev et al. *Evaluated activation cross section data for proton induced nuclear reactions on W up to 3 GeV incidence energy*. Number 7628 in KIT Scientific Reports. KIT Scientific Publihing, 2012.

[639] 'Predisposal management of radioactive waste, including decommissioning.' IAEA Safety Standards Series No. WSR-2, International Atomic Energy Agency, Vienna, 2000.

[640] D. Ene. 'Transport of radioactive waste from ESS.' Technical Report, European Spallation Source, 2012.

[641] 'Regulations for the safe transportation of the radioactive material.' IAEA Safety Standards Series No. SSR-6, International Atomic Energy Agency, 2012.

[642] D. Ene. 'Shielding calculations for ESS high activated target system.' Technical Report EDMS 1242978, European Spallation Source, 2012.

[643] 'Development of specifications for radioactive waste packages.' IAEA TECDOC 1515, International Atomic Energy Agency, Vienna, Oct 2006.

[644] D. Ene. 'Proposal for approach to be used for determining 3H release reduction.' Technical Report ESS-0001921, European Spallation Source, 2011.

[645] M. Jensen et al. 'Controlling the tritium contents in cooling helium.' Technical Report EDMS 1230258, European Spallation Source, 2012.

[646] M. Jensen. 'Management of operational emissions and waste.' EDMS 1225860, Hevesylab, Risø, 2002.

[647] L. Jacobs. Private communication, 2012.

[648] C. Kharoua. 'Filtering system for the potential tungsten dust.' Technical Report EDMS 1192485, European Spallation Source, 2012.

[649] R. Moorman. 'Dust borne activities in gas-cooled spallation sources experience from gas cooled reactors and from fusion devices.' Technical Report EDMS 1185536, European Spallation Source, 2011.

[650] P. Nilsson. 'Purification guesstimates.' Technical Note 1251578 ver. 0.1, European Spallation Source, 2012.

[651] United States Department of Energy, http://www.hss.doe.gov/nuclearsafety/techstds/docs/handbook/index_hdbk1169.html. *DOE nuclear air cleaning handbook*, last accessed Apr 20, 2013.

[652] 'Management of waste containing tritium and carbon-14.' IAEA Technical Reports Series TRS-421, International Atomic Energy Agency, Vienna, Jul 2004.

[653] K. Liger. 'Private communication.' CEA Cadarache, 2012.

[654] K. Andersson and S. Nielsen. 'Intake of tritiated water vapour released from ESS facility airborne releases.' Technical Report EDMS 1241368, DTU Nutech, Technical University of Denmark, 2012.

[655] D. Ene. 'Intake of tritiated water vapour and radioactive carbon released from ESS facility: Airborne releases, synthesis of work.' Technical Report ESS1241368, European Spallation Source, 2012.

[656] K. Andersson et al. 'Methodology to be used for detailed calculation of dose factors (discharge limits) during operation of the ESS facility.' Technical Report EDMS 1225821, European Spallation Source, 2012.

[657] K. Andersson et al. 'Inhalation and ingestion doses from the most important potential contaminants from routine airborne releases at ESS.' Technical report EDMS 1225821, European Spallation Source and DTU Nutech, Technical University of Denmark, 2012.

[658] 'Argos System.' http://www.argos-system.org, last accessed 19 Feb 2013.

[659] J. Ehrhardt. 'The RODOS system: Decision support for off-site emergency management in Europe.' *Radiation Protection Dosimetry*, 73(1–4), 1997.

[660] S. P. Nielsen and K. G. A. (editors). 'PardNor – PARameters for ingestion dose models for NORdic areas – Status report for the NKS-B activity 2010.' Technical Report, Risoe National Laboratory for Sustainable Energy, Technical University of Denmark, Roskilde, Denmark, Jan 2011. ISBN 978-87-7893-304-1.

[661] K. G. Andersson and S. P. Nielsen. 'External doses from the most important potential contaminants from routine airborne releases at ESS.' EDMS 1259513, European Spallation Source and DTU Nutech, Technical University of Denmark, 2012.

[662] 'Forschungszentrum Jülich.' http://www.fz-juelich.de, last accessed 25 Nov 2012.

[663] T. Hansson. 'Specification for revised dose assessment.' Technical Report ESS-00000056/1, European Spallation Source, 2012.

[664] K. G. Andersson and S. P. Nielsen. 'Radionuclides to be considered in dose estimates following accidental airborne releases.' Technical Report EDMS 120905, European Spallation Source, 2012.

[665] K. Andersson and S. Nielsen. 'Note on evaluation of doses received from airborne releases due to a hypothetical severe design basis accident (DBA) at the ESS installation.' Technical Report ESS-1246094, European Spallation Source, 2012.

[666] C. H. Sen. 'Preliminary decommissioning plan for ESS.' Technical Report N-11/179, Studsvik Nuclear AB, 2011.

[667] Swedish Ministry of the Environment. 'Sweden's fourth national report under the Joint Convention on the safety of spent fuel management and the safety of radioactive waste management.' Ds 2011:35, Ministry Publications Series, Stockholm, 2011.

[668] 'Decommissioning of small medical, industrial and research facilities.' IAEA Technical Reports Series TRS-414, International Atomic Energy Agency, 2003.

[669] 'Decommissioning of medical, industrial and research facilities.' IAEA Safety Standard Series WS-G-2.2, International Atomic Energy Agency, 1999.

[670] 'Decommissioning of nuclear facilities other than reactors.' IAEA Technical Reports Series TRS-386, International Atomic Energy Agency, 1999.

[671] L. Teunckens et al. 'Decommissioning of the Eurochemic reprocessing plant, strategies, experiences and developments.' In *Decommissioning in Belgium: Proceedings of the Belgian Nuclear Society Annual Conference*. 1999.

[672] 'Financial aspects of decommissioning.' IAEA TECDOC 1476, International Atomic Energy Agency, 2005.

[673] *Summary of the ITER Final Design Report*. International Atomic Energy Agency, Vienna, Jul 2001.

[674] K. S. Jeong et al. 'Structures and elements for the decommissioning cost estimations of nuclear research reactors.' *Annals of Nuclear Energy*, 34:326 –332, 2007.

[675] 'Selecting strategies for the decommissioning of nuclear facilities, a status report.' Technical Report (originally published in *Radioactive Waste Management*) No. 6038, Nuclear Energy Agency (NEA) and Organisation for Economic Co-operation and Development (OECD), 2006.

[676] 'Design lessons drawn from the decommissioning of nuclear facilities.' TECDOC 1657, International Atomic Energy Agency, 2011.

[677] 'Managing low radioactivity material from the decommissioning of nuclear facilities.' IAEA Technical Reports Series TRS-462, International Atomic Energy Agency, 2008.

[678] M. Rogante. 'Contributions to the decommissioning issue of the ESS project.' RE-ESSHU-01-2009, Rogante Engineering, Cinitanova Marche, 2009.

[679] 'Studsvik AB.' http://www.studsvik.com, last accessed 19 Feb 2013.

[680] 'Wikipedia: Studsvik.' http://en.wikipedia.org/wiki/Studsvik, last accessed 16 Nov 2012.

[681] 'SKB.' http://www.skb.se, last accessed 19 Feb 2013.

[682] 'Regulation on operation of accelerators and sealed radiation sources.' Swedish Radiation Safety Authority SSMFS 2008:27, 2008.

[683] 'Safety culture.' Technical Report INSAG-4, International Nuclear Safety Advisory Group of the International Atomic Energy Agency, 1991.

[684] ‘Key practical issues in strengthening safety culture.’ Technical Report INSAG-15, International Nuclear Safety Advisory Group of the International Atomic Energy Agency, 2002.

[685] S. Nordlinder et al. ‘Preliminary safety analysis report for ESS.’ Technical Report ESS-0000002/1, European Spallation Source, 2012.

[686] R. Moormann. ‘Safety & licensing of the European Spallation Source (ESS).’ Report Jul 4136, Forschungszentrum Jülich, 2004.

[687] ‘Regulation on basic regulations for protection of workers and public at activities with ionisation radiation.’ Swedish Radiation Safety Authority SSMFS 2008:51, 2008.

[688] S. Nordlinder. ‘Dose assessment for severe accidents at ESS.’ Technical Report ESS-0000488/1, European Spallation Source, 2012.

[689] ‘Safety of nuclear power plants: Design, requirements.’ IAEA Safety Standard Series NS-R-1, International Atomic Energy Agency, 2000.

[690] C. Kharoua. ‘Design calculation report, estimation of the impact of the after heat – LOCA.’ Technical Report EDMS 1164510, European Spallation Source, 2011.

[691] ‘Registration, evaluation, authorisation and restriction of chemical substances (REACH).’ European Community Regulation No. 1907/2006, http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm, last accessed 22 Feb 2013.