News from NMI3
Development of Neutron Detectors for Very High Resolutions and Counting Rates

In the JRA DETNI (DEtectors for Neutron Instrumentation) three novel modular thermal neutron area detector types, based on thin solid neutron converter layers, are being developed for time- and wavelength-resolved neutron detection in single-neutron counting mode, with two-dimensional spatial resolutions of up to 50-100 µm FWHM, sub-microsecond time-of-flight resolution and counting rates of up to $10^9$ neutrons/s per detector module, i.e. for coping with the highest resolution and rate requirements at next generation pulsed spallation sources like ESS. Recording only signals above noise in single-event counting, the image contrast is greatly improved in comparison to integrating detectors, like CCD cameras or image plates. In addition, by scanning in a single measurement a full wavelength train, in time-of-flight radiography-tomography the contrast of individual elements in the sample is enhanced specifically in element-specific resonances of the total neutron scattering cross section. In addition to imaging, applications e.g. in time-of-flight Laue diffraction, very-high resolution single crystal diffraction and reflectometry are envisaged, among others. The detector types are:

- Four-fold segmented modules of Silicon micro-strip detectors (Si-MSD), with each segment comprising a $^{157}$Gd converter layer between two double-sided Si sensors of 51 · 51 mm² sensitive size and with 80 µm pitch in the X and Y micro-strip readout planes.
- Hybrid low-pressure micro-strip gas chamber (MSGC) detectors of 254 · 254 mm² sensitive size with three-stage gas amplification gaps and novel two-dimensional position-sensitive multilayer MSGC plates either side of a composite $^{157}$Gd/CsI converter which is coated with columnar CsI secondary electron emitter layers.
- CASCADE detectors with stacks...
of cascaded GEM (Gas Electron Multiplier) foils on either side of a double-sided, two-dimensional position-sensitive readout electrode. The GEM foils are coated on both sides with $^{10}$B converter layers and drift the secondary electrons, released in the gas by the secondary ions emitted form $^{10}$B after neutron capture, to a last GEM foil where they are amplified for two-dimensional detection. For readout, in DETNI two novel self-triggered high-rate ASIC (Application Specific Integrated Circuit) chips [1], subsequent ADC-FPGA boards with Gigabit glass fiber readout links and the required data acquisition firmware and software are being developed. The ASICs, a low-noise 128-channel chip optimized for the Si-MSD and strip rates of 160 khits/s, and a 32-channel chip optimized for the MSGC with variable amplification and strip rates of 900 khits/s, deliver spatial, analogue amplitude and fast time stamp information with 4 and 2 ns resolution, respectively, the latter being necessary for X-Y strip correlation with low chance coincidence rate. The amplitude readout is used for improving the spatial resolution by center-of-gravity interpolation between the strips and for gating for background suppression. Prototypes of all three detector types are being prepared presently together with the readout electronics for testing in 2007.

References
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Neutron Optics and Phase Space Transformers

The most efficient means for increasing the flux at beam lines for neutrons is the use of advanced focusing techniques based either on diffractive optics or the reflection of neutrons from surfaces that are coated with artificial multilayer structures termed “supermirror”. In addition, the flux can be increased by actively changing the phase space of the radiation, for example by cooling the spectrum of the neutrons and/or by moving monochromators. Of course, the flux can also be increased by increasing the source strength as it is for example done in the US and Japan, where new high-power spallation sources are being built and commissioned.

The goal of the JRA3-collaboration is the development and exploration of new focusing techniques and phase space transformations that allow for the investigation of small samples as they occur often in the fields of soft condensed matter and in materials research as well as materials exposed to extreme conditions, for example high magnetic fields and/or high pressure. In order to increase the neutron flux for small angle neutron scattering (SANS), a multi-beam collimator has been developed, featuring 7 masks with 51 pinholes each. First test experiments using a suspension of Latex spheres with a diameter of 225 nm prove that the principle is working leading to the expected flux gains while maintaining the resolution. For inelastic neutron scattering experiments, the Q-resolution can often be significantly relaxed. Therefore, a concept of focusing devices concentrating the neutron beams by reflection from supermirror-coated glass tubes that are elliptically curved has been developed. A flux gain of approximately 25 has been measured using neutrons with a wavelength in the range 3 Å < \lambda < 6 Å. In order to increase the efficiency further, improved coating techniques using magnetron sputtering have been developed thus increasing the number of diffracting layers from 500 to several thousand. The systematic studies have led to an improvement of the coatings with respect to the critical angle (m = 4.2)
MUONS – Instrumentation for Spin-Polarized Muon Spectroscopy

Muons provide a unique probe of atomic level structure and dynamics and the experimental technique is known as Muon Spin Rotation, Relaxation and Resonance (µSR).

A wide variety of properties can be investigated across a broad range of systems, including magnetic materials, superconductors, semiconductor and molecular/polymeric systems.

A muon can be thought of as a microscopic magnetometer, with spin 1/2 and a magnetic moment three times that of the proton, and can be used to inform on local magnetic structure and dynamics.

The muon mass is approximately one-ninth that of a proton, and in many experiments muons are used as a mimic to determine proton or hydrogen sites and dynamics, for example in semiconductors, metal hydrides and proton conductors.

Muons provide a complementary probe of condensed matter to other techniques such as neutron scattering and magnetic resonance, and are used by many research groups across Europe. This JRA is aimed at advancing technologies in a number of areas relevant to the performance of muon experiments.

These advances will benefit the whole European muon community, and are aimed at enhancing the capabilities of the European muon facilities to extend their potential for condensed matter investigations.

Specifically, this JRA is aimed at developments in three areas:

1. Detectors for muon spectroscopy; in particular, development of fast-timing detectors and those capable of providing position information.
2. Instrument simulation; in particular, the development of code to enable full simulation of muon spectrometers.
3. Advanced experimental methods, in particular development of novel pulsed techniques.

State-of-the-art

Detectors

Position sensitive detectors: our recent studies have shown that, in addition to silicon-based detectors, scintillating fibres too are very promising as position-sensitive detectors for µSR. A detailed work including both simulation and testing, has shown the equivalence of signals generated by muon-decay-positron with those arising from common beta emitters: this will make future test procedures simple.

Fast and magnetic field insensitive detectors: the performance Avalange-Photo-Diods/SiPMs detectors at low temperatures is at present known in a cryogenic environment. Mechanical difficulties concerning the assembly of the AMPD array on printed circuit boards, will be overcome by using light guides for signal transmission. Detailed Monte Carlo simulations for an improved light output and an increased efficiency are being carried out. The results will be used in the design of a revised version of the detector layout. Beside being very fast (some tenths of ns), the response of the blue-sensitive AMPDs, is expected to be also magnetic field independent, as already shown for their green sensitive counterparts, making them an ideal choice for the detector system of a high-field spectrometer.

Simulations of detectors and spectrometers

Efforts were devoted to the inclusion of positron track simulations into the existing simulation code, and in particular in the test against real data. The magnetic field-dependent effects were investigated by using a purposely built positron detector, which includes two mobile detecting elements mounted inside a superconducting solenoid. The observed effects seem to depend not only on the cyclotron motion of the positrons, but also on the field induced motion of the muons in the incoming beam.

Advanced µSR techniques

The development of µSR in pulsed environments, e.g. microwave and RF-µSR, has been the main focus. The technology associated with crossed-coil RF excitation has now developed to the point where techniques dependent on this technology (e.g. g-value determination and RF nuclear decoupling) make a regular contribution to the ISIS user programme. RF decoupling, in par-
Development of Methods for Biological Deuteration

The DLAB JRA within NMI3 is focused on the development of methods for the efficient and cost-effective deuteration of biological macromolecules. The project is fully dedicated to biological neutron scattering, but has an important link to solution and solid state NMR. The methods that are being developed as part of the project are now starting to have an impact on biological neutron scattering experiments on solutions, fibres, crystallography and dynamics. Real results in these areas that have benefited from these methodological developments are now coming into the scientific press. In very broad terms, DLAB work cover the following general areas:

1. Methods aimed at driving down the cost of deuterated biomolecules, thereby enhancing access. This is being done through the development of new methods to optimise bacterial growth. Two approaches are being deployed here (I) the development of bacterial strains that are more tolerant of D$_2$O and deuterated carbon sources, (II) fundamental proteomic approaches in which the molecular networks involved in adaptation are investigated.

2. Methods aimed at developing the use of new organisms for deuteration/labelling, thereby extending the range of systems that can be deuterated. Here techniques are being developed to label organisms such as Ralstonia eutropha and the eucaryotic organism Pichia pastoris to provide vehicles for the expression of heterologous proteins that can not be expressed in E. coli.

3. Optimisation of methods for the selective deuteration of biological macromolecules so that the visibility of particular regions of these structures is enhanced in modelling. A variety of approaches are being developed, ranging from methods whereby particular residues are deuterated to those that facilitate macro-scale labelling of large multi-component systems.

4. Methods aimed at optimising selective hydrogenation of complex biological systems to enable hydrogen incoherent scattering studies of specific components. Techniques for the hydrogen labelling of specific amino acids in deuterated membrane proteins are being extended to various prokaryotic and eukaryotic systems of major biological interest. Over and above the specific technical goals, the DLAB project aims to extend its activities and expertise as widely as possible throughout the European neutron scattering community. Within the current framework this is gradually happening via the network of neutron scattering partners and NMR observers within the DLAB project. It is also happening through the dissemination of results from successful deuteration/labelling projects that have exploited the expertise developed. Many of these have used neutron scattering facilities at the ILL, but experiments on labelled systems have also been carried out at ISIS (where reflectometry results have complemented ILL SANS measurements and ssNMR studies, both also exploiting the labelling) and at Juelich (where measurements from the BSS spectrometer have complemented data from other spectrometers with different energy resolutions).

Clearly the involvement of all European neutron scattering facilities involved in biological work is essential and this is a primary concern for this JRA in the context of FP7. One intriguing aspect emerging from current activities is the fact that neutron/NMR complementarity is not restricted to mutual benefit simply through labelling requirements. New neutron proposals are indeed emerging as a result of the NMR deuteration & labelling work because NMR users are discovering first hand the value added to their work through the use of neutrons. There is little doubt that the same could be said of many other techniques.

Trevor Forsyth
JRA7 – D-LAB Coordinator
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Cesare Bucci
JRA8 – MUONS Coordinator
As a result of progress in the field of Multiwire Proportional Chambers (MWPC), Microstrip Gas Counters (MSGC) and associated electronics, the performance of neutron gas detectors have constantly improved over the last three decades. Nevertheless, it is obvious that the experimental conditions imposed by future spallation sources will not be fulfilled by present gas detectors. This situation, together with a strong demand to improve existing instruments, explains why detector development has been given high priority within the NMI3 project (Neutrons & Muons Integrated Infrastructure Initiative).

The MILAND (Millimetre resolution Large Area Neutron Detector) Joint Research Activity aims to deliver, by the end of 2007, a fully operational detector of 32 cm x 32 cm sensitive area having a spatial resolution of 1 mm FWHM.

Considering other parameters like gamma sensitivity, counting rate, uniformity, and robustness, we expect the performances of the MILAND detector to exceed those of existing neutron detectors. During the first two years of the project, several techniques have been studied and one of them has been selected:

1. the principle of a GSFC (Gas Scintillating Proportional Chamber) is based on the detection of light emitted during the charge avalanche process around thin anodes, producing about hundred times more light than in a solid scintillator. The spatial resolution measured with several prototypes was bellow the specification, but promising ideas emerged from this study: in particular we proposed to exploit the electron drift information to measure the third coordinate of the neutron capture, providing a new method for correcting parallax error of gas detectors;

2. MSGC are made of metallic strips engraved on a substrate by photolithography, and polarised at a high voltage to create gas amplification; they have been also considered for the MILAND detector due to their unique detection performances in counting rate and spatial resolution. Since the size of one single MSGC can’t cover the full area of the MILAND detector, it is necessary to mount several of them side by side, at least 4; it was not been possible to demonstrate in time the feasibility of a continuous sensitive area without dead zone;

3. the MILAND detector will be finally made of a MWPC using a 15 bars pressure vessel, filled with 2 plans of 320 cathodes wires at a pitch of 1 mm, mounted on each side of the anode plan, and connected individually to a fast amplifier and discriminator circuit. The main difficulty encountered was to find the conditions to maintain long anode wires polarised at a high voltage with a distance of only 1 mm between them. As a result of experiments performed with different prototypes, the following parameters have been optimised to reduce the high voltage value, and its effect on the wire stability: gas mixture, detector geometry, wire diameter and mechanical tension, amplifier specifications, and signal processing. The construction of the pressure vessel has started at KFKI (Budapest-Hungaria); the acquisition system is under study at FRM-II (Munich-Germany), the wire electrodes are in fabrication at GKSS (Hamburg-Germany); the analog electronics and digital processing are studied at the ILL (Grenoble-France).

In parallel to the construction of the final detector, we continue to study more speculative detection techniques like those based on the avalanche light. New prototypes are under study at LIP (Coimbra-Portugal), at ISIS (Didcot-UK) and at the LLB (Saclay-France). Diffractometers in operation on the neutron sources of today will benefit from the MILAND detector, but for future spallation sources like the SNS (US) scheduled in 2006, the JSNS (Japan) in 2007, and the ESS (European Spallation Source), which is expected to start its operation within the next decade, the need for detectors with larger angular coverage will still be unsatisfied, particularly in the field of NMC (Neutron Macromolecule Crystallography). Several of the techniques discussed, or studied during the course of the MILAND project could be used to develop a solid neutron converter cylindrical detector with a sub-millimetre resolution.

Bruno Guerard
JRA 2 – MILAND Coordinator
Polarised Neutron Techniques

Polarized neutron scattering provides exceptional possibilities for detailed understanding of the mechanisms involved in phenomena at the forefront of condensed matter research. Co-operative efforts of partners representing 11 European research facilities allows not only for significant improvements of parameters of polarized neutron instruments, but also for the break through long existing limits. The following are just few examples of current progress. Measurement of the vector properties of the neutron polarization provides a unique way of recovering the significant directional and phase information lost when only neutron intensities are measured. Practically, three components of the polarization vector can be determined by neutron polarimeters. JRA partners have significantly contributed in the construction of a new affordable non-cryogenic 3-d neutron polarimeter MUPAD. The Larmor precession of neutron spin in magnetic field allows for attaching a specific label to each of the neutron in the beam. Such Larmor labeling is the basis of a new neutron scattering instrumentation with an extremely high energy and momentum resolution that is not achievable in conventional neutron spectroscopy (dip fraction) because of intolerable intensity losses. Further development of neutron spin-echo spectrometers – new correction elements – is pushing the energy resolution limit beyond 1 neV, thus opening a new horizon for studies of extremely slow dynamics in condensed matter. As to the angular measurements, intensive efforts of partners are resulting in the further development of Larmor precession based instrumentation for reflectometry, SANS and diffraction. Particularly, in neutron reflectometry angular resolved measurements perpendicular to the scattering plane become possible allowing for studies of complicate planar nanostructures. To further propagate these powerful and fruitful methods in the neutron scattering community the School on polarized neutron scattering has been held in Berlin (HMI) in September this year, where beside listening to lectures given by experienced polarized neutron scientists, more than 30 participants carried out their own first experiments at polarized neutron instruments.

Alexander Ioffe
JRA5 – PNT Coordinator

Virtual Neutrons: MCNSI

MCNSI is an acronym for: “Monte Carlo simulations of Neutron Scattering Instruments”. This activity deals with the fast ray-tracing of neutrons for scattering purpose – in contrast to the much more detailed neutron transport simulations used in nuclear physics (e.g. MCNP). The speed of the ray-tracing simulations is usually sufficient to perform simulated experimental results of good quality within minutes to hours. The basis of the MCNSI activities is the development of three general-purpose Monte Carlo packages: McStas, VITESS, and RESTRAX. The utilization of the packages takes place among more than 100 instrument responsible and neutron simulators worldwide. Important in this respect is the intercomparison between packages, which can be done at a very accurate level, as well as the comparison between simulations and experiments (with slightly less accuracy due to unavoidable uncertainties in the experimental set-up). The value of the intercomparison is very significant, since it adds confidence to all packages. This is one important argument for maintaining more than one simulation package. Another argument is that fruitful developments within one package will spread to the others through the MCNSI collaboration. As an example neutron polarization has recently been added to McStas, inspired by VITESS. The most pronounced results from MCNSI is covered by the concept of “virtual experiments”. This is a vision of completely describing a neutron scattering experiment from the source, over all optical elements, to the sample, including sample environment and detectors. Virtual experiments can be used to design instruments, perform feasibility studies, prepare experimental set-up, design sample environment, and understand non-idealities in data (as misalignments, multiple scattering, non-Gaussian resolution functions, etc). A number of virtual experiments have been performed within MCNSI, but there is still some development needed before this is a useful tool for the general instrument scientist. The first web-based virtual experiments for feasibility and preparation purposes are expected to be on-line early 2007 at the PSI diffractometer DMC. The virtual experiment con-
Neutron Spin Filters. To Revolutionize the Polarized Neutron Applications

The $^3$He neutron spin filter (NSF) has started to revolutionise polarised neutron experiments. The $^3$He nucleus, which is extremely absorbing to neutrons to the point that it is an excellent gas for neutron detectors, can be spin polarised by very efficient methods. It becomes a filter for the neutron spin having very promising properties. Since January 2004, a consortium of 6 European facilities, namely CEA-MDN, FRM-II, FZJ, HMI, ILL and ISIS, actively develop advanced modular devices with the aim of improving and widening the exploitation of spin filters. This work focuses on the production of polarised $^3$He gas using both the spin-exchange (SEOP) and metastability-exchange (MEOP) optical pumping techniques and the exploitation of the polarised gas on instruments with improved containers and diverse magnetic chambers necessary for maintaining the $^3$He polarisation.

For the past two years, ILL has modified its polarised $^3$He filling station and obtained very impressive results: the maximum polarisation has raised from 75 to 83% and the production rate has doubled, reaching 15 bar.l/day. In the meantime, FRM-II has acquired a filling station showing almost identical performance. HMI is finishing the construction of its own MEOP filling station and ISIS has greatly improved its SEOP station, the maximum polarisation moving from 32 to 70%.

The relaxation of the $^3$He polarisation scales with the surface-to-volume ratio and depends strongly on the quality of the inner surfaces of the $^3$He containers. After many investigations at all facilities and some fruitful discussions with colleagues from the USA, we have finally adopted a reliable recipe leading to the production of containers with long relaxation times (200 to 450 hours). Some work has also been done to build large containers that could be efficiently used in front of large neutron detectors. With the help of companies producing special equipment in clean rooms, we have constructed and...
tested very successfully a banana-shaped \(^3\)He spin filter covering a wide-angle (120°) and featuring a low decay of the \(^3\)He polarisation. This success opens the door to the application of \(^3\)He spin analyser new neutron sources. We have also designed, constructed and tested a chamber made of \(\mu\)-metal and permanent magnets for hosting NSF cells maintaining the \(^3\)He polarisation on neutron beams. It can screen low environmental magnetic fields, protects the users from accidental explosion of the container, does not require the use of a battery during transport and maintains the polarisation efficiently. By adding a solenoid producing an oscillating radiofrequency magnetic field, the chamber can also flip the polarisation of the \(^3\)He nuclei and therefore selects the polarisation state of the neutron beam. With such a device, the NSF is becoming a very practical device that is going to be widely used at many neutron facilities.

Eddy Lelièvre-Berna
JRA4 – NSF Coordinator

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**News from SNS**

**Recent Progress in ORNL’s Neutron Sciences Directorate**

**Summary**
The Neutron Scattering Science Advisory Committee met November 30 - December 1, 2006. The triennial Basic Energy Sciences Review of the SNS will occur December 6-8, 2006. On November 19, a four-hour run of the Spallation Neutron Source was completed at a power level of 60kW at 15Hz.

**Instruments**
The High Flux Isotope Reactor (HFIR) began installation of the shutters and collimators for the new guide system. Following this, the installation of the final sections of guide is planned for February 2007. The two new SANS instruments at HFIR are complete and ready for commissioning with neutrons. The operating software (based on the popular SPICE program) is being tested. The Scientific Computing Group has enabled HFIR data to flow to the data management system at SNS, and began archiving and backing up existing HFIR data. The three operating instruments at SNS (Backscattering Spectrometer, and the Magnetism and Liquids Reflectometers) continued commissioning. Data collected at 30 kW and 60 kW during the last run cycle demonstrate that the instrument performance will meet expectations.

**Operations**
The High Flux Isotope Reactor (HFIR) continues preparations for reactor restart in spring 2007. SNS operations are scheduled for all of November. The typical week is 3 days of neutron production, 3 days of acceleration physics, and one day of maintenance. The next scheduled maintenance period is December 1 - January 15. For the October run period, the 514 hours of beam time corresponded to almost 75% of the total planned beam time. Integrated beam power to Target was 1.095 MW-hours in October. On November 19, a four-hour run at a power level of 60kW at 15Hz was completed.

Two notable achievements:
- SNS now delivers the highest proton intensity per pulse in routine operation of any pulsed spallation neutron source. Recent operation delivered 6.8 microcoulombs/pulse, or 4.3x10^{13} protons/pulse;
- In dedicated accelerator physics studies, the SNS set a new world record for the most intense bunched proton beam, with 0.9x10^{14} protons accumulated, bunched, and extracted from the ring.

**Employment Opportunities**
Employment opportunities are periodically available in the Neutron Sciences Directorate or are related to neutron scattering at ORNL. Click on “View Open Positions” at http://jobs.ornl.gov/

**Future meetings and deadlines of interest to SNS and HFIR users**
For current information, please visit the website http://www.sns.gov/calendar/index.shtml.
- Educational workshop on neutrons in materials science, Oak Ridge Chapter of ASM, April 18, 2007;
- Industrial applications of neutrons, April 19, 2007, Oak Ridge, TN;
- Residual Stress Summit, October 2-4, 2007, Oak Ridge, TN
- SNS-HFIR User Group Meeting, October 8-10, 2007, Oak Ridge, TN
• Center for Nanoscale Materials Sciences User Meeting, October 10-12, 2007, Oak Ridge, TN
• 4th Workshop on Inelastic Neutron Spectrometers (WINS), Oak Ridge, TN fall 2007
• Sessions on biointerphases and magnetism during the American Vacuum Society fall meeting October 13 – 18, 2007, Seattle, WA
• American Crystallographic Association, Annual Meeting, May 31-

June 5, 2008, Knoxville, TN

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The Los Alamos Neutron Science Center featured in Report

The Los Alamos Neutron Science Center (LANSCE) is the subject of the recently released Issue 30 of Los Alamos Science, a publication highlighting the science activities of Los Alamos National Laboratory. Today the LANSCE state-of-the-art facilities operate simultaneously for national security and fundamental science research. The facilities, including the Lujan Neutron Scattering Center, the WNR Center, Isotope Production Facility, and Protron Radiography Facility, contribute to nuclear research, nuclear medicine, materials science, nanotechnology, biomedical research, electronics testing, and fundamental nuclear physics, in addition to other areas. Some specific future plans include:

• Delivering very intense fast neutrons at the Materials Test Station to explore radiation-tolerant materials for advanced nuclear energy options;
• Commissioning of an Ultra-cold Neutron Source facility to make high precision tests of the standard model of elementary particle physics;
• Upgrading the Proton Radiography Facility to enable high-resolution of physics of importance to national security;
• Enhancing the existing Lujan Neutron Scattering Center to ensure its competitiveness in neutron scattering;
• Developing a long-pulse neutron source prototype to explore techniques for achieving a hundred-fold increase in neutron flux.

The entire issue is available electronically at www.lanl.gov/science.

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The Lujan Neutron Scattering Center at LANSCE.