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The MERLIN Chopper Spectrometer at ISIS

R.I.Bewley¹, R.S.Eccleston¹, J.R.Treadgold¹, R.L.S.Coleman¹, D.W.J.Bellenger¹,
N.J.Rhodes¹, K.A.McEwen², S.M.Hayden³, M.T.Dove⁴

¹*ISIS Facility, CCLRC Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire,
OX11 0QX, UK.*

²*Department of Physics and Astronomy, University College London, Gower Street,
London, WC1E 6BT, UK.*

³*H H Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol, BS8 1TL, UK*

⁴*Department of Earth Sciences, University of Cambridge, Downing Street,
Cambridge, CB2 3EQ, UK*

Abstract

A new chopper spectrometer, MERLIN, is being designed and constructed at the ISIS Facility. MERLIN is optimised to provide high flux at medium energy resolution. The primary spectrometer will be equipped with a converging supermirror guide and provision for the installation of polarising devices at a later date. A secondary flight path of 2.5m means a detector solid angle of approximately π Sr is achievable. The sample tank and detector assemblies have been designed to provide coverage of $\pm 30^\circ$ vertically and 180° horizontally using position sensitive detectors (PSDs) whilst minimising gaps.

The specifications and design considerations of the spectrometer will be presented and the current status of the project will be reviewed.

It is anticipated that MERLIN will be commissioned in 2005.

1. Introduction

MERLIN is a new chopper spectrometer currently being constructed at ISIS to replace the High Energy Transfer (HET) chopper spectrometer. The design objectives are high count-rates with medium resolution, high angular coverage and performance that is complementary to the existing ISIS chopper spectrometers MARI and MAPS. Furthermore, it is anticipated that high count rates will suit parametric studies so the ability to use difficult sample environment equipment, such as pressure cells and large magnets, is an important design criterion, and provision for the incorporation of polarizing filters at a later date is being made. A schematic of the instrument is shown in figure 1.

The key components of the spectrometer are a supermirror guide, to enhance the flux onto the sample and a large detector bank, to provide angular coverage in the range -45° to $+135^\circ$ in

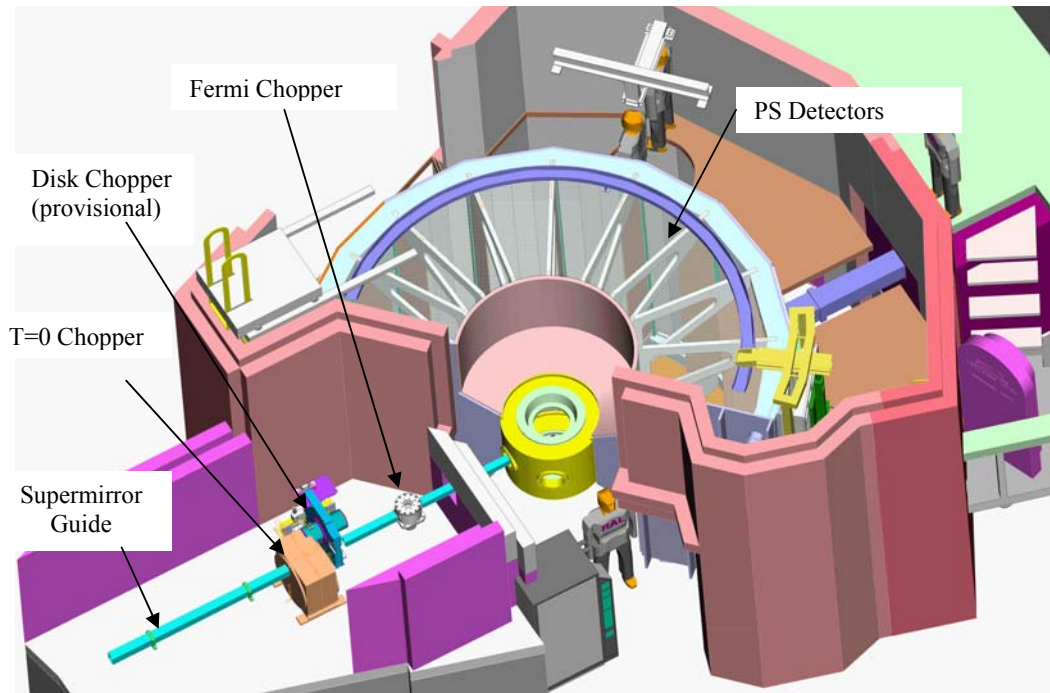


Figure 1. Cut-away drawing of the MERLIN spectrometer showing the principal components.

the horizontal plane and $\pm 30^\circ$ in the vertical plane with a minimum scattering angle of 3° at a distance of 2.5m from the sample, equipped with position sensitive detectors. The T=0 and Fermi choppers are essentially of the same design as those used on the other ISIS chopper spectrometers, although consideration is being given to the development of a new Fermi chopper system with a high transmission, which will be reported elsewhere¹. The requirement to reduce background scattering from massive sample environment will be met by the option to install an oscillating radial collimator in the scattered beam and the use of beam defining jaws in the incident beam so the beam size can be tailored to suit the apertures of sample environment equipment. Provision is being made in the design for the installation of polarizing filters in the incident and scattered beam at a later date.

2. Moderator and Primary spectrometer

It was originally envisaged that MERLIN would be located on beamline N9, which is currently occupied by HET. However, with the removal of the KARMEN neutrino bunker beam ports S4 and S5 have become available. Locating MERLIN on beamline S4, between MARI and SXD, offers: the opportunity to continue to operate HET throughout the construction of MERLIN, greater flexibility with regard to the position of MERLIN, and the ability to choose the optimum moderator characteristics. The S4 moderator will only be viewed by MERLIN whereas HET shares a moderator with five other instruments and its characteristics are essentially a compromise between the requirements of these instruments. HET views an ambient water moderator poisoned by a gadolinium foil at 15cm which, with a 12m primary flight path, provides a best resolution of order 2.5% incident energy at the elastic line. The water moderator is well-suited to MERLIN because it offers additional flux above 40meV, and the objectives of medium resolution with high incident flux mean that a broader moderator pulse can be tolerated. Complementarity also argues in favour of the water

moderator because MARI views the methane moderator and provides a good flux for incident energies below 40meV with wide angular coverage and good resolution.

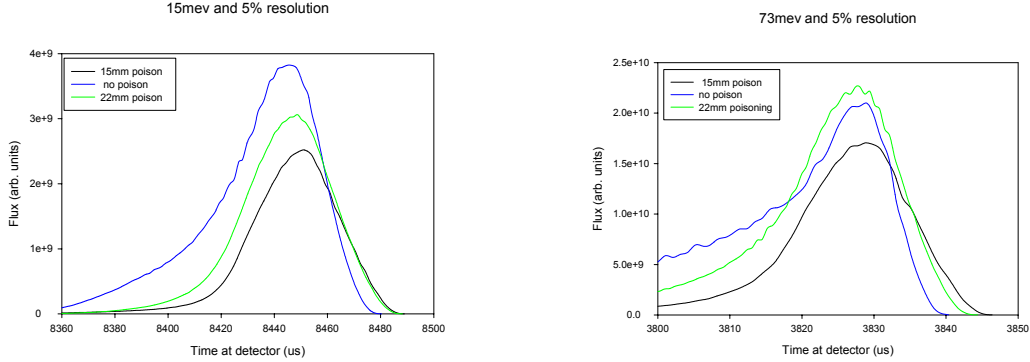


Figure 2 Peak shapes for three moderator configurations for an incident energy of 15meV and 73meV, both at 5% energy resolution.

Several scenarios for the moderator have been studied, including the removal of the poisoning altogether, increasing the poisoning depth to 22mm and leaving it at 15mm. Figure 2 illustrates the consequences of each scenario in terms of the pulse width at the detector. The un-poisoned moderator provides the highest flux, but the peak shape is broad and asymmetric, too broad to provide less than 3% energy transfer resolution. The optimisation of the moderator which most closely satisfies the MERLIN design goals is a poisoning depth of 22mm, providing flux gains for the same resolution compared with 15mm poisoning (as used on HET) as described in the table below. It is only when the resolution approaches 2% that the flux for the 15mm poisoned moderator surpasses that of the 22mm moderator.

Energy meV	Gain (5% resolution)	Gain (3.5% resolution)	Gain (2% resolution)
15	1.2	1.15	0.4
73	1.3	1.23	0.82

Table 1. Ratio of peak flux heights at the detector for 22mm poisoned moderator to the 15mm poisoned moderator.

The flux at the sample for a given incident energy is proportional to the solid angle of the moderator as seen by the sample and the open time of the chopper as a fraction of the flight-time from moderator to chopper.

$$\Phi = \left(\frac{p}{d} \right) \left(\frac{WmHm}{(L_1 + L_3)^2} \right) \left(\frac{\Delta t_{cc}}{L_1} \right)$$

The term (p/d) refers to the ratio of the width of the chopper transmitting slits to the width of the absorbing slats, the second term to the solid angle of moderator viewed by the sample (Wm and Hm are the width and height of the moderator respectively) and the third term to the chopper burst time. L_1 , L_2 and L_3 are moderator to Fermi chopper, sample to detector and

Fermi chopper to detector distances respectively. While the use of supermirror guides can reduce the $(L_1+L_3)^2$ flux loss, particularly for cold and thermal neutrons, the decrease in flux as L_1 increases, arising from the third term, is always present. Consequently from the point of view of flux the instrument should be as close to the moderator as physically possible. However, the length, L_1 , will also dictate the minimum accessible energy resolution. For the case of MERLIN, 3% resolution is deemed to be appropriate which for a 22mm poisoned moderator fixes the primary flight path at 11.8m. This is 2m closer to the moderator than would have been possible on beamline N9.

The MERLIN supermirror will start 1.7m from the moderator with a square 94mm aperture and be straight in the shutter section. Thereafter it will converge to give a beam size at the sample of 50mm x 50mm. Monte Carlo simulations have demonstrated the straight section does not impact on the flux compared to a guide converging throughout its length. It has a further advantage in that it simplifies the engineering of these components and means that the modulations in the flux occurring as a consequence of small changes in the shutter alignment are reduced.

Although the super-mirror guide increases the neutron flux it also has the effect of increasing the beam divergence in an energy dependent manner, and consequently Q resolution will be degraded, particularly for low energies. The Q resolution as a function of scattering angle has been calculated for MERLIN for a range of incident energies (figure 3). For most experiments that are envisaged for MERLIN, this Q resolution is reasonable, however, for those experiments that will require better Q resolution, the option of a collimator in the incident beam will be available

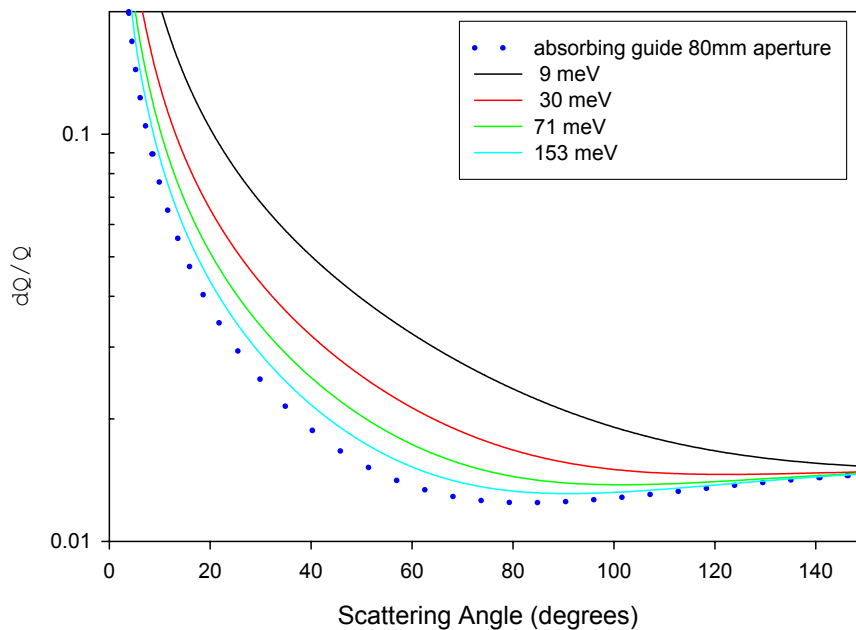


Figure 3. *Q* resolution is presented for various energies as a function of scattering angle. The energy resolution has been fixed at $dE/E=3\%$.

3. Sample/Detector Tank and Detectors

The original design of MERLIN featured 1m position sensitive detectors like those used on MAPS, tiling approximately π Sr of solid angle on the surface of a sphere. The shortcoming of the approach, which is exacerbated with a secondary flight path as short as 2.5m, is that it gives rise to horizontal and vertical gaps in the detector coverage. For the original MERLIN tank design, the vertical gaps meant that five detectors were lost for every 32, amounting to a loss in detector coverage of approximately 15%. The revised MERLIN design features a curtain of vertical detectors (figure 4). This introduces a path length difference between the pixels in the equatorial plane, which are 2.5m from the sample, and those at the extreme edges of the detector bank, which are approximately 2.9m from the sample. This results in a difference in energy resolution of approximately 10%. However, this difference is tolerable, and can be dealt with in the data analysis software. This configuration reduces the vertical gaps, but because the whole tank is evacuated, supporting struts are required which will also create gaps in the detector coverage. A further refinement of the tank design is to position the detectors inside the vacuum tank. A system of doors and seals has been designed which allows the detector tubes to be positioned inside the tank but with the electronics still in air thereby negating any arcing problems that might occur if the electronics were in the vacuum tank during evacuation. Obviously thin vacuum windows are no longer required and the doors that house the detector assemblies now add strength to the tank. Gaps equivalent to 2 detectors in width are still required, but these are designed to coincide with absorbing vertical vanes that prevent spurious scattering from detector to detector across the tanks. Initial tests to evaluate the vacuum integrity of this design have been successful.

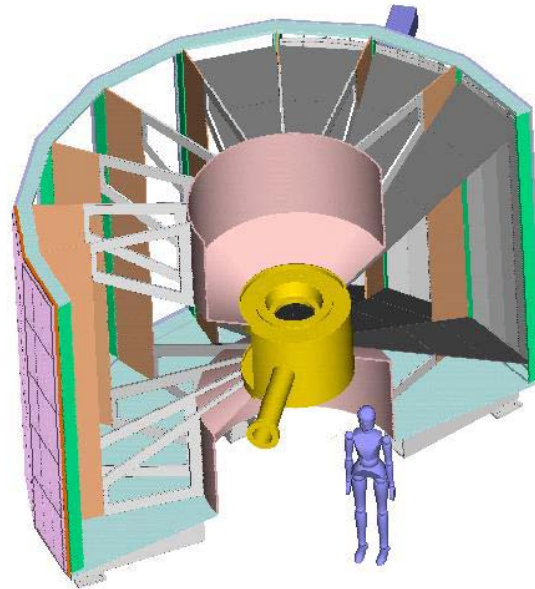


Figure 4. The MERLIN sample/detector tank.

The availability of long ^3He PSD tubes, of up to 3m in length, offers the opportunity to tile the whole detector tank without any horizontal gaps. Long detectors have been tested using electronics based on the MAPS design², but with a 12-bit rather than an 8-bit ADC. The spatial resolution obtained is equivalent to 15mm FWHM, which surpasses the necessary specification, while the background signal remains equivalent to the MAPS detectors.

4. Summary

MERLIN has been designed to provide rapid data rates with high angular coverage. Simulations suggest that the combination of an $m=3$ supermirror guide, optimization of the

moderator and the guide geometry will provide an enhancement in flux onto the sample of up to 15 times that of HET (approximately 9 times at 50meV, 5% energy resolution). By using a cylindrical detector tank design, putting the detectors inside the vacuum tank and using 3m long position sensitive detectors, a solid angle of approximately π Sr will be covered by some 50000 pixels with minimal gaps in the coverage. The solid angular coverage will be approximately seven times that of MAPS, MARI and HET. MERLIN has been optimized to operate in the medium energy resolution regime, to provide a high data rate compliment to the higher resolution capabilities of MAPS and MARI.

5. References

¹ R.I.Bewley, in preparation

² C.D.Frost et al, Proceedings of the 14th Meeting of the International Collaboration on Advanced Neutron Sources, Starved Rock Lodge, Utica, Illinois, USA, June 14-19, 1998, Argonne National Laboratory Report ANL-98/33, ISSN 1560-859X. June 1998. Editors J. M. Carpenter and C. A. Tobin.