Nuclear Instruments and Methods in Physics Research A 853 (2017) 16–19

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

# The thermal triple-axis-spectrometer EIGER at the continuous spallation source SINQ

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ARTICLE INFO

*Keywords:*
Triple-axis-spectrometer
Neutron spectrometer
Spallation source

ABSTRACT

EIGER is the new thermal triple-axis-spectrometer at the continuous spallation SINQ at PSI. The shielding of the monochromator consists only of non- or low magnetizable materials, which allows the use of strong magnetic fields with the instrument. This shielding reduces the high energy neutron contamination to a comparable level of thermal spectrometers at reactor sources. The instrument design, the performance and first results of the spectrometer are presented.

## 1. Introduction

Since the early days of neutron scattering triple-axis-spectrometers (TAS) are the most commonly used instruments for inelastic neutron spectroscopy of single crystals at continuous neutron sources. Spallation neutron sources are typically pulsed where direct time-of-flight instruments are favorable. The only continuous spallation neutron source is SINQ at PSI [1] and the instrumentation at SINQ is similar to reactor based sources and very different to other spallation sources. Up to 2012 at SINQ there were two cold TAS but no thermal one. One reason for this is that at a spallation source there are more high energy neutrons with even higher energy, than at a reactor [2,3]. For cold neutron instruments this is not relevant since the instruments are built at neutron guides far away from the neutron source. Since the neutron guides are much less effective for thermal neutrons than for cold neutrons, a large distance between neutron source and monochromator would reduce the neutron intensity of a thermal TAS at SINQ to an inacceptable level. As a consequence the high energy neutrons make the design of a thermal TAS, where low background is very important, more challenging at a continuous spallation source than it is at a reactor based source.

In this paper we report on the design, performance and first results of the thermal TAS EIGER at the continuous spallation source SINQ.

## 2. The EIGER instrument

### 2.1. General design

Fig. 1 shows the layout of the instrument. The primary instrument consists of a beam tube with a sapphire filter, a virtual source, a double-focusing pyrolytic graphite (PG) monochromator and the shielding. The secondary instrument of the former cold TAS DrüchaL was upgraded and is now in operation at EIGER. It is similar to that of the cold TAS TASP [4]. It is equipped with a horizontal focusing PG analyzer and a single tube $^3$He detector.

### 2.2. Beam tube

A water scatterer, placed within the heavy water moderator tank, provides EIGER with neutrons. The entrance window has size of 80×150 mm$^2$. Behind the entrance window there is a 100 mm sapphire filter which reduces the flux of neutrons with energies above about 100 meV. The beam tube up to the virtual source is converging with an exit window of 40 mm width and is equipped with a neutron super-mirror and includes three rotatable steel cylinders used as high energy neutron shutters. Unfortunately, an unknown amount of the super-mirror coating peeled off which causes some loss of intensity especially at lower neutron energies. After the virtual neutron source with an adjustable width between 0 and 40 mm, there is space in the shielding which can be used for a neutron velocity-selector which is intended to

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http://dx.doi.org/10.1016/j.nima.2017.02.003
Received 17 November 2016; Received in revised form 1 February 2017; Accepted 1 February 2017
Available online 03 February 2017
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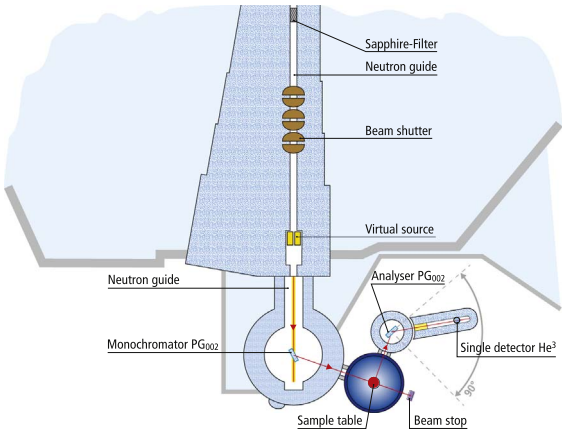


**Fig. 1.** Sketch of the instrument EIGER.

be installed at the next upgrade of EIGER.

### 2.3. Monochromator shielding

The main task of the shielding is an efficient reduction of the γ- and fast neutron radiation. It is important that the shielding does not become too thick otherwise the monochromator-sample distance would become too large which would reduce the intensity at the sample position. An additional requirement for the EIGER-shielding is that it should contain only low-magnetizable materials, since the instrument is intended to be used also in combination with high magnetic fields. Therefore, a composite design with layers of mainly the four materials: tungsten-paraffin wax mixture, lead, low-magnetizable heavy concrete and borated polyethylene was selected. A more detailed description of the shielding can be found in [5]. The tungsten-paraffin composition is used in the region where the highest fast neutron fluxes occur and where space limitations are most disturbing the operation of the instrument. The Tungsten-paraffin block is shielded by a Cadmium layer which ensures that only a low amount of thermal neutrons will activate the compound. Most of other parts are made of low-magnetizable heavy concrete with a density of about 5.2 g/cm$^3$. The concrete is loaded with 5% boron carbide to improve the absorption of slowed down neutrons. A further goal of the monochromator shielding design was to reduce the neutronic background which can hit the sample or even worse the detector system. The goal was reached by a triangular surface, filled with boron Carbide, of the inner part of the monochromator which acts as a neutron trap.

Within the monochromator shielding there is sufficient space for additional monochromators, which might complete the instrument in later upgrades.

### 2.4. Monochromator

Fig. 2 shows a picture of the present PG monochromator. The design of the monochromator is similar to that of MACS [6]. The 135 PG pieces have a mosaicity of about 0.5 degree and a size of 20×20 mm$^2$. Nine pieces of the PG are screwed on each of the 15 Al lamella, therefore the total surface of the PG on the monochromator is 300×180 mm$^2$. Vertical focusing of the monochromator is achieved by bending, horizontal focusing by rotating the lamella. The advantage of this design of a double focusing monochromator is that there is only very small amount of material in the beam. Therefore, the contribution of neutrons scattered at supporting material of the monochromator is reduced to a minimum. However, the bending of the lamella for vertical focusing causes a shift of the PG crystals which has to be compensated by a translation of the whole monochromator in order to avoid any misalignment.

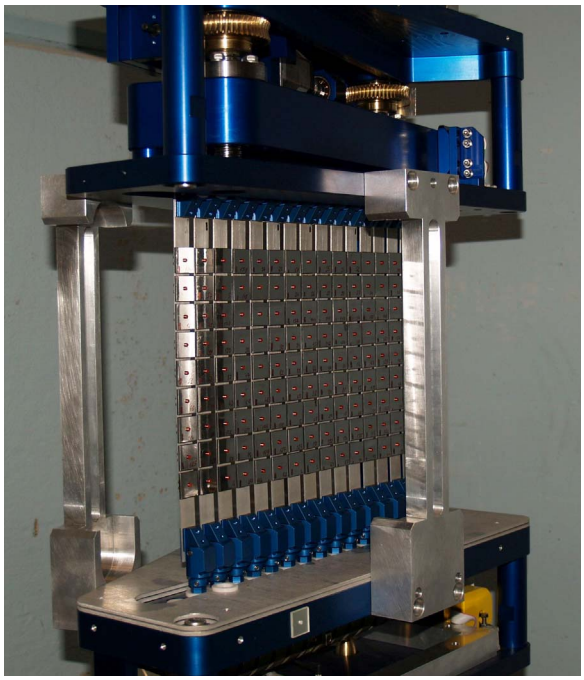

**Fig. 2.** Picture of the EIGER monochromator.

**Fig. 3.** Picture of the monochromator shielding, sample table and the secondary spectrometer with the analyzer housing and the detector shielding of EIGER.

### 2.5. Secondary instrument

A picture of the secondary instrument and the monochromator shielding is given in Fig. 3. The distances between monochromator - sample and sample - analyzer are variable with minimum distances of 2530 mm and 1090 mm, respectively. The sample table can be rotated and is equipped with two goniometers for tilting the sample. The PG-analyzer, 175×150 mm$^2$ in size, has a horizontal focusing option, but no vertical curvature. The detector is a vertical $^3$He-tube with a diameter of 50 mm and a height of 170 mm. The effective width of the detector can be reduced by a slit in front of the detector. Typically a slit of 20 mm is used in combination with the horizontal focusing of the analyzer. Soller collimators with a collimation of 20′, 40′ or 80′ can be inserted after the monochromator, after the sample and after the

analyzer. A PG-filter of 37 or 70 mm length can be used in order to suppress higher order contamination of the detected neutrons.

### 2.6. Sample environment

All standard sample environments can be used on EIGER, including the cryo-magnets. Since the shielding of the monochromator and the analyzer are built nearly free of magnetizable materials it is not necessary to increase the distances to the monochromator and analyzer when cryo-magnets are in use. Due to their motors, the goniometers have to be removed when cryo-magnets are in operation and the tilting option is not available. The horizontal magnets can be used without any further restrictions. With the currently available magnets at PSI the vertical magnetic field is restricted to 13 T due to the steel reinforcement in the concrete of the floor.

## 3. Performance and examples

The neutron flux at a spallation source is proportional to the proton flux onto the target and the design and material of the target itself. Therefore, the neutron flux on the sample and intensity at the detector of EIGER depends also on these parameters and will vary with each target used at SINQ. The flux density at the sample position and has been estimated in 2011 with a calibrated monitor at the sample position to $5.8{\cdot}10^6$ n/sec/cm$^2$ at a typical proton flux of 1.5 mA and a nominal neutron energy of 13.1 meV. The background was determined with a vacuum box at the sample position, open beam and without any collimations to about 2 – 3 counts per minute, independent on the incident neutron energy. In Fig. 4 the incoherent spectrum of a Vanadium rod with a diameter of 10 mm is shown. The energy of the incident neutrons was 14.68 meV, the monochromator and analyzer were focused and therefore no collimators were used. The elastic energy resolution in this configuration is about 0.7 meV.

With increasing energy transfer the resolution matching between primary and secondary becomes worse at TAS instruments, especially when the lattice spacings of the Bragg reflections at the monochromator and the analyzer are similar. This mismatch causes a significant loss of performance. In order to reduce this mismatch often different types of crystals at the monochromator and the analyzer are used. At EIGER the (004) PG reflection at the monochromator instead of the (002) reflection can be used for this purpose. This reduces the intensity by a factor of about three but improves the energy resolution by a factor of nearly two at energy transfers above about 15 meV. Fig. 5 shows an example were this option has been chosen to distinguish phonons, magneto-elastic excitations and crystal field excitations in $Tb_2Ti_2O_7$ [7].

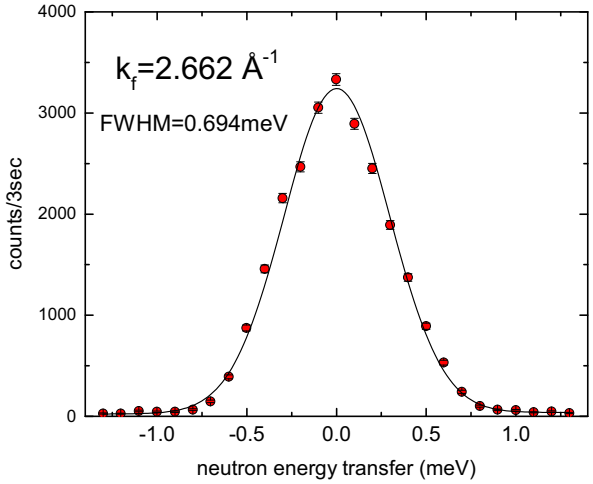


**Fig. 4.** Incoherent elastic spectrum of Vanadium measured at EIGER.

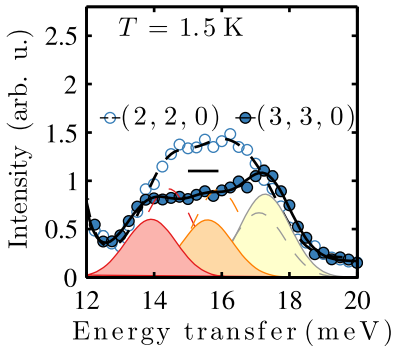


**Fig. 5.** Excitation spectra from Ref. 7 of $Tb_2Ti_2O_7$ close to 16 meV at two different reciprocal lattice points. The spectra were measured on EIGER in the high resolution configuration where the (004)-reflection of the PG monochromator was used.

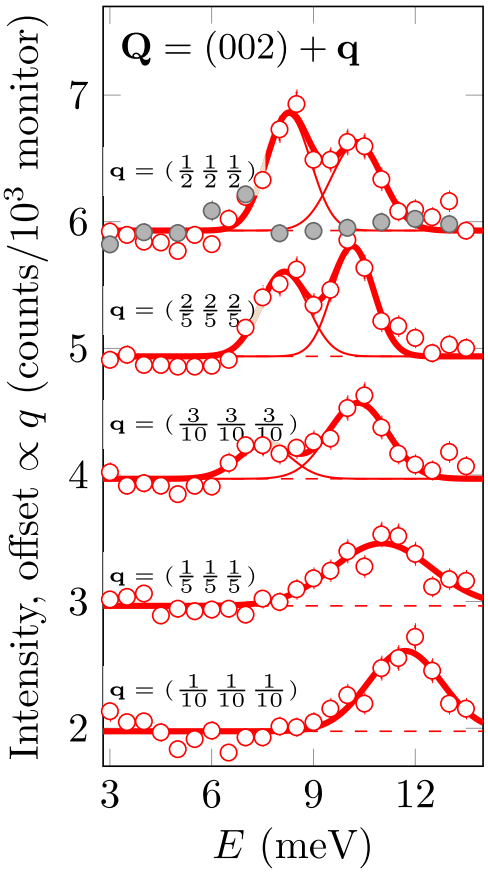


**Fig. 6.** Splitting of the magnon mode in the skyrmion host $Cu_2OSeO_2$ measured on EIGER in the standard configuration with fixed final neutron energy of 14.6 meV [8].

A second example of an experiment at EIGER is given in Fig. 6. It shows an unexpected splitting of a magnon mode along the Γ-R direction in reciprocal space of the skyrmion host $Cu_2OSeO_2$ [8].

## 4. Conclusion

In conclusion we could show it is possible to build successfully a thermal TAS close to a spallation source. A sophisticated design of the low-magnetizable shielding reduces the background caused by fast neutrons and the total performance of EIGER is comparable to modern state-of-the-art TAS at reactor sources.

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