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FOCUS: A NEW TIME OF FLIGHT SPECTROMETER AT THE NEUTRON SPALLATION SOURCE SINQ/CH

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ABSTRACT

The design of the time-of-flight (TOF) spectrometer FOCUS to be built at the SINQ at the Paul Scherrer Institute is presented. The main purpose is to provide a versatile TOF machine well suited for a large variety of applications. The concept of the instrument consists in the combination of a doubly- and variably-focusing monochromator with a Fermi chopper. By changing the optical conditions FOCUS will have the option to be operated either in time- or monochromatic-focusing mode, for quasielastic and inelastic scattering measurements, respectively. The expected performances of FOCUS are presented and compared to the existing IN6-TOF spectrometer at the Institute Laue-Langevin (ILL).

1. Introduction

The Swiss spallation neutron source SINQ is expected to produce the first neutrons at the end of '96. FOCUS (Focusing Crystal University Spectrometer) is the project of a new time of flight (TOF) spectrometer for cold neutrons at this source. It is being built in cooperation between the 'Universität des Saarlandes, FRG', the 'Forschungszentrum Jülich, FRG' and the 'Paul Scherrer Institut, CH'.
Within the 'day-1' instrumentation FOCUS will be the only TOF spectrometer. Therefore the physical design should provide a versatile and highly flexible instrument to be suited for a wide range of applications. The concept of FOCUS consists in a hybrid TOF spectrometer combining a crystal monochromator focusing both horizontally and vertically with a Fermi chopper. Equipped with two interchangeable monochromators (pyrolithic graphite and mica) the spectrometer will continuously cover a band of incoming energies $0.25 \text{ meV} \leq E_i \leq 20 \text{ meV}$, thus touching also the thermal neutron regime.
The spectrometer will be located at the end of the curved guide RNR11 viewing the cold D_2-source.

Keywords: Time of Flight Spectrometer, Focusing, Fermi Chopper, SINQ

2. Components

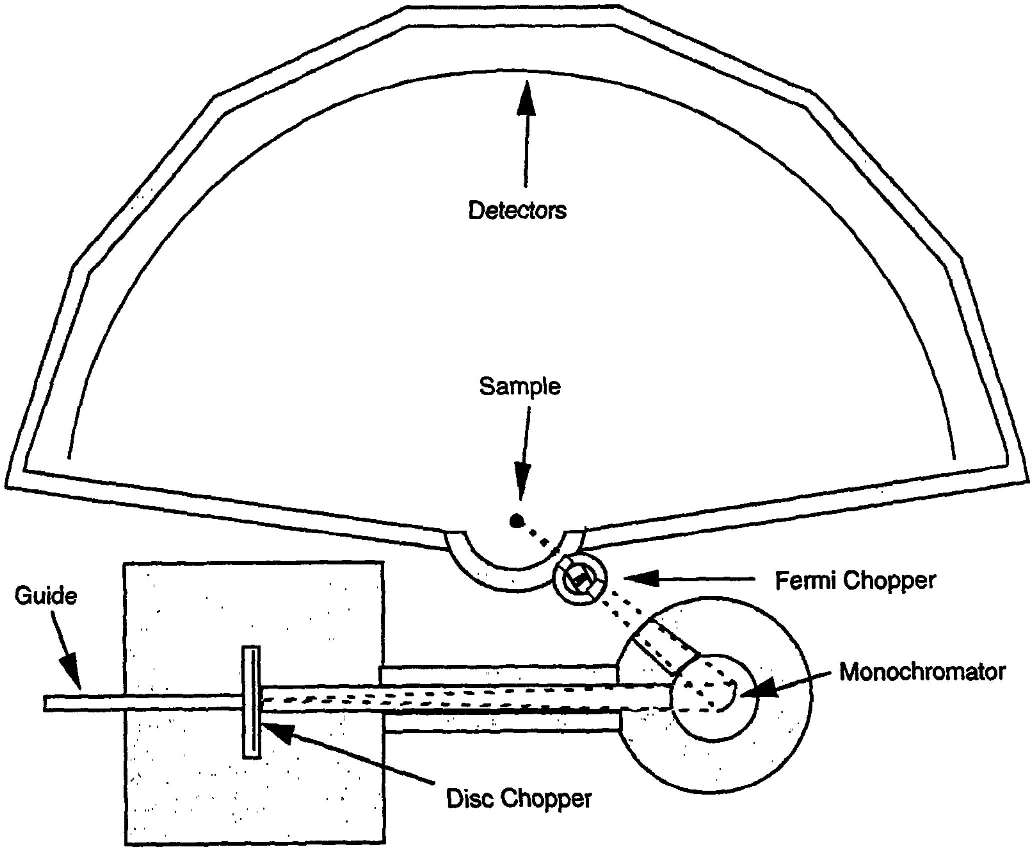

Fig. 1 Schematic drawing of FOCUS and its main components

Table 1: Relevant spectrometer parameters

Component		Dimension
guide	horizontal	5 cm
	vertical	12 cm
converg. guide	vertical	12 cm →10 cm
distance	guide - disc chopper	0.2 m
	guide - monochromator d_{gm}	1.5 - 3 m
	monochromator - sample d_{ms}	1.5 - 3 m
	Fermi chopper - sample	0.5 m
	sample - detectors	2.5 m
monochromator	horizontal	16 cm
	vertical	21 cm
	mosaic η (PG)	$(0.8\pm0.1)^\circ$
	Take-Off Angle	$35^\circ < 2\theta < 140^\circ$
Fermi chopper :	frequency ν :	<330 Hz
	window: horizontal	6 cm
	vertical	10 cm
	collimation Σ :	1-3°
disc-chopper:	diameter:	70 cm
	frequency:	<165 Hz

Figure 1 presents a schematic drawing of the spectrometer layout. By means of a vertically converging guide (G), the white beam is first reduced from 12 x 5 cm^2 (h x w) to 10 x 5 cm^2 and then chopped by a disc chopper (DC). The horizontally and vertically focusing monochromator (M) with variable curvature in both directions focuses the beam through a Fermi chopper (FC) onto the sample. The disc chopper will also prevent higher order contamination and frame overlap. At the sample (S) position the beam has the dimension 6x3 cm^2. In its first stage FOCUS will be equipped with 200 ^{3}He counter tubes (D) of rectangular cross section, covering a scattering angle range from -34^0 to 130^0. Two further banks of detectors can be added so that FOCUS will run on 600 counter tubes in its final stage. In between sample position and detectors a He-filled box is placed to prevent scattering from air. For incident energies $E_i \leq 4.8$ meV optionally a cooled Be-Filter can be placed in the monochromator shielding. The dimensions of FOCUS are listed in table 1.

3. Time- versus monochromatic-focusing

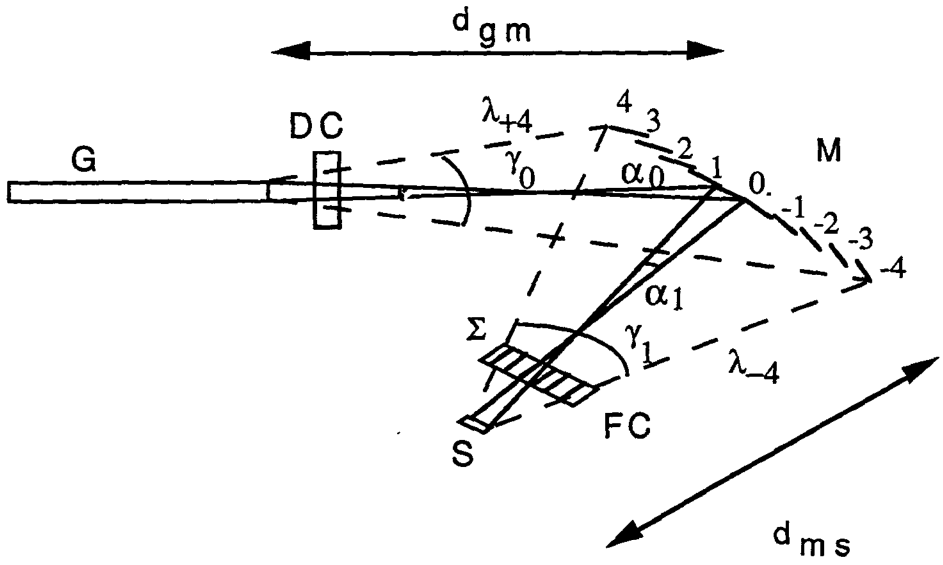

Fig. 2 Horizontal cut of the focusing monochromator

A copy of the existing IN6 (ILL)[1, 2] spectrometer would not be appropriate at the SINQ. Indeed the high divergence and the large size of the beam available at the end of the guide RNR11 would have a detrimental effect on both the energy resolution and the intensity.

Consider an arrangement in which the distance d_{gm} between the end of the guide and the monochromator can be increased (Fig. 2). Thus, for each individual piece of the monochromator, the wavelength uncertainty decreases since the local collimation α_0 decreases. On the other side the intensity at the sample position remains almost unaffected if the horizontal and vertical curvature of the monochromator are adjusted to focalise the beam onto the sample.

The overall wavelength band delivered by a curved monochromator is given by[3]

$$\Delta\lambda = |\lambda_{-n} - \lambda_n| = (\lambda_i/2)\cot(\Theta)|\gamma_1 - \gamma_0| \tag{1}$$

Where λ_i is the incident wavelength, θ is the monochromator angle and γ_0, γ_1 are the aperture angles of the monochromator. Clearly, two configurations are possible:

3.1 Monochromatic focusing

If one desires a good resolution over a wide energy-transfer range, it is necessary to focus monochromatically ($\Delta\lambda = 0$). For that purpose the distances d_{gm} and d_{ms} have to be equal. This arrangement allows to work with a relaxed collimation Σ of the Fermi chopper. This means a large intensity gain since firstly, the cross-section is directly proportional to Σ [4] and secondly, the dynamic transmission is improved (especially for long wavelengths and high frequencies).

3.2 Time focusing

$\Delta\lambda \neq 0$ ($\gamma_1 \neq \gamma_0$ or $d_{gm} \neq d_{ms}$) and the time-focusing principle has to be used, i. e., the Fermi chopper allows the slow neutrons to start before the fast ones in such a way that they will reach the detectors at the same time. The Fermi-chopper frequency is determined by the time focusing condition and the Fermi-chopper collimation has to be adjusted such that the sample is viewing only one monochromator piece. Unfortunately the time focusing mode is valid for one energy transfer only, thus being inadequate for scattering processes over a large energy transfer range.

4. Expected performances of FOCUS

Intensities and energy resolutions for several spectrometer configurations have been calculated for the proposed spectrometer as well as for IN6-ILL. We used both analytical expressions[4] and a modified version of a Monte Carlo simulation program developed by H. Mutka[3]. The results using both methods are very similar and Table 2 gives the values obtained for an incident wavelength of 6 Å. The first solid target at the SINQ should deliver a flux $\partial\sigma/\partial\Omega$ at the end of the guide RNR11 of the order of one third of the flux measured at the IN6-ILL guide. The next generation targets (either solid or liquid) should allow to increase the flux by a factor of 3. Therefore, considering these uncertainties, the flux $\partial\sigma/\partial\Omega$ has been set to unity in all calculations.

Table 2: calculated performances of FOCUS for several configurations. The values obtained for the IN6 spectrometer at the ILL and an IN6-type spectrometer at the SINQ are also included.

	λ=6 Å Instr. Type	$I/(\partial\sigma/\partial\Omega)$	Resol. (μeV) ΔE=-2 meV	Resol. (μeV) ΔE=0 meV	Resol. (μeV) ΔE=10 meV	Comments
	IN6-ILL					
1	145 Hz	1.00	66	45	850	Time-foc.
	FOCUS					
	d_{gm} / d_{ms} / Σ / ν					
2	3.0/ 1.5/ 1/ 260	0.26	47	35	690	Time-foc.
3	3.0/ 1.5/ 1/ 160	0.67	46	54	1140	
4	1.5/ 1.5/ 3/ 160	1.82	26	85	1060	Monochr.
5	3.0/ 3.0/ 3/ 330	0.86	26	47	580	Monochr.
6	3.0/ 3.0/ 3/ 330	0.42	13	46	580	Monochr.

All intensities are given relatively to the instrument IN6-ILL and we included in our intensity calculations an anti-overlap condition for Fermi-chopper frequencies higher than 160 Hz. For comparable resolutions at the elastic position, FOCUS (row 3 (R3) and R5) will reach about 80% of the intensity of IN6-ILL (R1).

The best resolution of FOCUS, at the elastic position, is achieved in the time focusing mode (R2). The monochromatic configurations (R4-R6) of FOCUS are the most attractive ones since it is possible to work either in high intensity mode (R4) or in high resolution mode (R6), with a good resolution over a large energy transfer range.

5. Conclusions

The physical design of the new hybrid TOF-spectrometer FOCUS in construction at the Swiss spallation source SINQ has been presented. By changing the optical conditions FOCUS will have the option to be operated either in time- or monochromatic-focusing mode, for quasielastic and inelastic scattering measurements, respectively. This flexibility is necessary since FOCUS will be the only "first generation" TOF instrument. The energy resolution has been calculated for several spectrometer configurations using a Monte Carlo algorithm and the expected performances of FOCUS should be very comparable to those of IN6 at the ILL. The flux at the sample position will be directly related to the performance of the target. For the 'day-1' experiments, the expected flux will be one third of the flux measured at the IN6-ILL guide.

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7. References

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