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Focus: Project of a Space and Time Focussing Time-of-Flight Spectrometer for Cold Neutrons at the Spallation Source SINQ of the Paul Scherrer Institute

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The physical design of FOCUS, a new time-of-flight (TOF) spectrometer for cold neutrons located at the continuous spallation source SINQ at the Paul Scherrer Institute/CH is presented. The main purpose of the instrument is to provide a versatile TOF machine being suited for a large variety of applications. The concept of the instrument consists in the combination of a doubly focussing monochromator with a Fermi-chopper. The monochromator will be provided with variable curvatures in both horizontal and vertical direction. By variable distances between the main spectrometer components FOCUS will have the option to be operated either in time focussing or monochromatic focussing mode for quasielastic and inelastic scattering applications, respectively. By means of two interchangeable monochromators a continuous wavelength band ranging from 2Å up to 18Å will be accessible. Monte Carlo simulations for an ideal Pb-target at SINQ show that for 4Å and 6Å and in its time focussing mode FOCUS will yield comparable energy resolutions in connection with 70–90% of the intensity of the time focussing TOF spectrometer IN6 at the ILL.

Keywords: time-of-flight; focussing; SINQ

1 INTRODUCTION

Viewing the present situation of time-of-flight instruments for cold neutrons it appears that there is a large gap between demands for beam time and the

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capacity of the existing facilities. Especially during the ILL-shutdown period the situation became dramatically bad. At that time only the MIBEMOL-spectrometer at the LLB, Saclay, France and the backscattering spectrometer IRIS at RAL, Chilton, UK, were in operation. After the ILL restart in spring '95 the situation has improved slightly due to IN5 and IN6, but still there is an overload of a factor 4–5 for the existing instruments.

At the same time the construction of the new Swiss spallation induced continuous neutron source SINQ [1] at the Paul-Scherrer Institute (PSI) proceeds rapidly and the first neutrons are expected within the second half of '96. It is therefore obvious to design a time-of-flight machine matching to the instrumentation frame at SINQ.

Within the 'day-1' instrumentation FOCUS (Focussing Crystal University Spectrometer) will be the only TOF spectrometer at SINQ. Due to that fact there is an essential demand to have a versatile instrument covering a wide range of applications, i.e. being suited both for quasielastic and inelastic neutron scattering studies. Thus, the instrument has to fulfill the following criteria: 1) energy resolution $\Delta E/E_i$ of a few percent at the elastic peak position, 2) good energy resolution over a wide range of energy transfers, 3) highest possible intensity. The concept of FOCUS therefore consists in a hybrid-TOF spectrometer combining a crystal monochromator focussing both horizontally and vertically with a Fermi-chopper. By means of variable distances between the main spectrometer components and the variable curvature of the monochromator the user will be enabled to operate FOCUS either in time focussing or monochromatic focussing mode depending on the experimental requirements.

Equipped with two interchangeable monochromators (pyrolithic graphite and Mica) the spectrometer will continuously cover a band of initial energies 20 meV$\geq$ E$_i \geq$ 0.25 meV corresponding to wavelengths 2Å $\leq \lambda_i \leq$ 18Å. Thus, FOCUS will cover the whole cold neutron energy range and will touch also the thermal neutron regime.

A direct copy of the time focussing TOF machine IN6 [2, 3] is not the most suited design for FOCUS due to the high divergence and the large width of the supermirror coated neutron guides at the SINQ [4]. Additionally, IN6 other than FOCUS is designed especially for quasielastic scattering applications.

The spectrometer will be located at the end of the curved guide RNR11 viewing the cold D_2-source. In Figure 1 the location of FOCUS within the guidehall is shown together with a survey of the other instruments at SINQ.

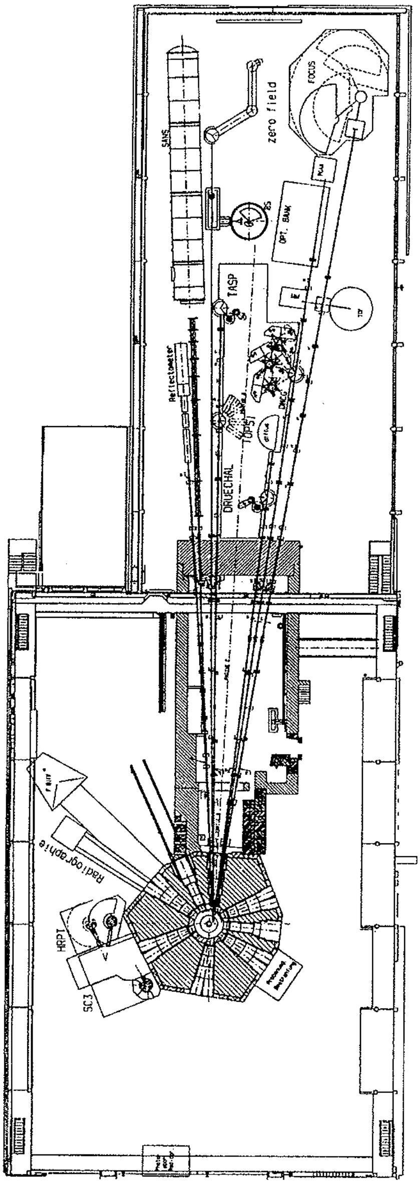

FIGURE 1 Survey of the experimental hall at SINQ. On the left hand side the target station is visible. FOCUS will be located at the end of the curved guide RNR 11 (in the lower right corner of the figure).

2 GENERAL LAYOUT

In the following our concept for the TOF spectrometer at SINQ is presented. Figure 2 presents a schematic drawing of the spectrometer layout. The end of the guide is designed as a vertically converging guide ('vertical anti-trumpet') to reduce the vertical dimension of the beam from 120mm to 100mm. The divergence of the beam gets slightly enlarged in vertical direction. This problem can be solved by the use of a vertically focussing monochromator, which has no detrimental effect on the energy resolution.

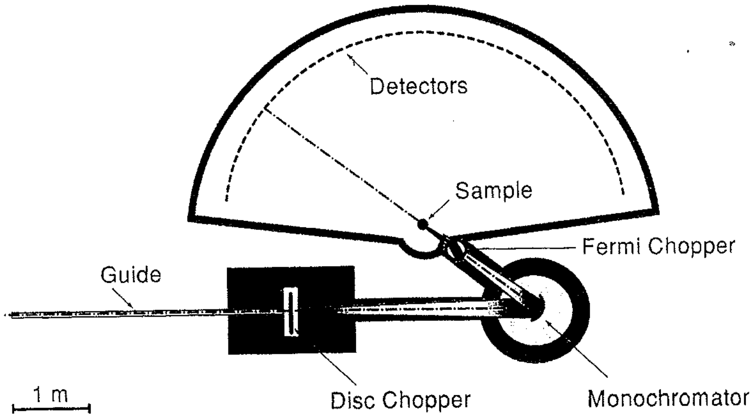

FIGURE 2 Schematic drawing of FOCUS and its main components (explanation see text).

Behind the converging guide the white beam is chopped by a disc chopper preventing higher order contamination and frame overlap from different order reflections. The horizontally and vertically focussing monochromator with variable curvature in both directions focuses the beam through a Fermi-chopper on the sample. In the time focussing mode the Fermi-chopper allows the slow neutrons to pass earlier than the fast neutrons. Thus, it scans the monochromator to focus neutrons of a certain energy temporally at the detector positions. For incident energies $E_i \leq 4.8$meV optionally a cooled Be-Filter is able to be placed within the monochromator shielding to prevent frame overlap with higher orders.

At the sample position the beam has the dimension 30×60 (h × v) mm^2. In its first stage FOCUS will be equipped with 200 ^{3}He counter tubes with rectangular cross section. In total the range of scattering angles from $-34°$ to $+130°$ is covered. 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.

The respective dimensions of FOCUS are listed in Table 1.

TABLE I Spectrometer parameters of the proposed TOF machine FOCUS.

Component	Symbol	Dimension
Guide		
(m = 2)	H_g	12 cm
	W_g	5 cm
(m = 3) - converging mirrors	H_g	10 cm
	W_g	5 cm
Sample		
	H_S	6 cm
	W_S	3 cm
Distances		
End of guide-Chopper 1	L_{gp}	0.2 m
End of guide-Monochromator	L_{gm}	(1.5–3.0) m
Monochromator-Chopper 2	L_{mf}	(1.0–2.5) m
Chopper 2-Sample	L_{fs}	0.5 m
Monochromator-Sample	L_{ms}	(1.5–3.0) m
Sample-Detectors	L_{sd}	2.5 m
Disc-Chopper		
Frequency	ν	≤10000 rpm
Diameter	d_p	0.70 m
Windows	H_p	0.10 m
	W_p	0.08 m
Fermi-Chopper		
Frequency	ν	≤20000 rpm
Window	H_f	0.10 m
	W_f	0.06 m
Collimation	Σ	2.4°
Monochromator		
Mosaicity	η	(0.8 ± 0.1)°
Take-off angle	$2\theta_m$	35–140°

As will be shown in Section 3.4.2 it might be interesting to run the spectrometer either in time focussing or monochromatic focussing mode. This can be achieved by variable distances guide-monochromator and monochromator-sample. On the one hand this is realised by adding an additional flight path in between the monochromator shielding and the Fermi-chopper such that the physical length of the spectrometer gets enlarged by a linear movement. On the other hand either a guide or an ordinary flight path is inserted between the disk-chopper and the monochromator in order to change the collimation distance as it is done in a small angle neutron scattering experiment.

3 SPECTROMETER COMPONENTS

3.1 Neutron Guide

The index of reflection of the Ni-Ti super-mirror guides coated at the PSI [4] will be twice (m = 2) that of natural Ni, thus allowing a four times higher acceptance solid angle and accordingly an increase of intensity. Figure 3 shows the calculated wavelength dependent intensity at the end of the guide, calculated for an ideal Pb-target, together with the values for the same guide with a ^{58}Ni coating and measured intensities at the ILL on H15 (cold source 1, IN6) and H512 (could source 2) [5]. Note that the first Zircalloy-Rod-Target will provide a neutron flux of the order of one third of the final Pb-target. We clearly see the effect of curvature since a sharp cut-off appears at about 2 Å.

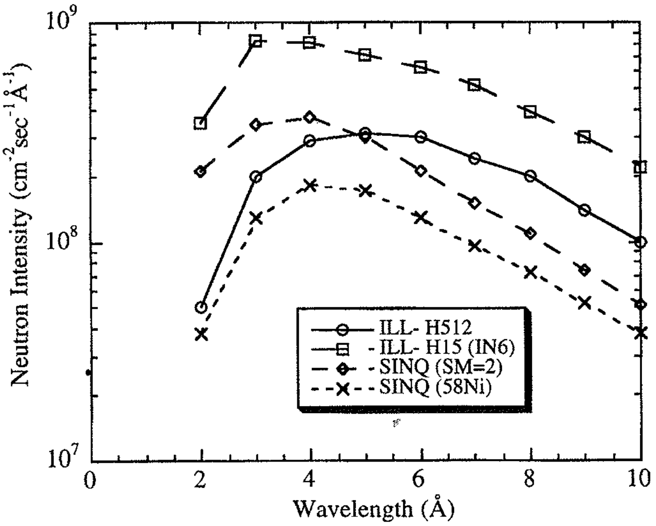

FIGURE 3 Wavelength dependent neutron flux at the end of a SINQ guide with super-mirror coating (m = 2) at 1mA proton current calculated for an ideal Pb-target. Also included are calculated values for the same guide with conventional ^{58}Ni - coating and two measured intensities for guides at the ILL viewing the cold sources 1 (H15) and 2 (H512).

The natural divergence γ_0 at the end of the guide is given by the critical angle and is wavelength dependent. Using Monte Carlo simulation techniques the angle distribution function can be shown to be trapezoidal [6]. The loss of intensity at high angles is due to both a lowering of the reflectivity and an increase of the number of reflections. For the Ni-Ti super mirrors with m = 2 used at SINQ we obtain values for FWHM of 1.2° and 1.6° at $\lambda_i = 4Å$ and $6Å$, respectively (see Figure 4).

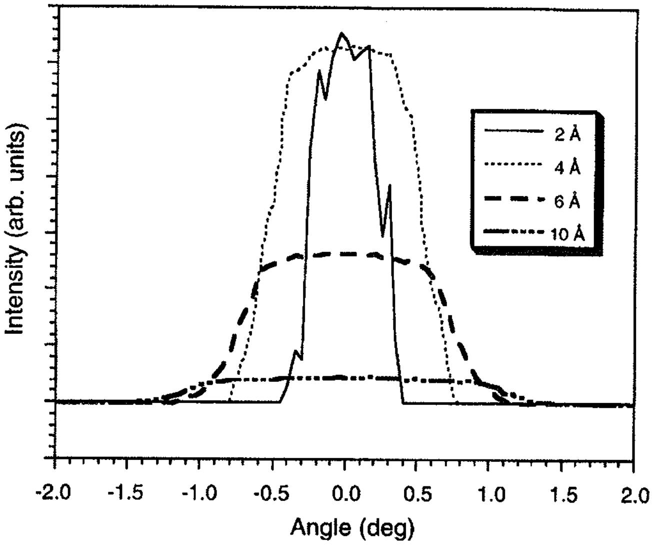

FIGURE 4 Calculated horizontal divergence distribution at the end of a SINQ guide with supermirror coating (m = 2) for several wavelengths [6].

In the case of FOCUS it might be favourable to reduce the vertical size of the beam by a converging neutron guide (m = 3) in vertical direction. Thus, also the vertical diameter of the pre-selector disc-chopper window gets reduced. At the present stage an 'anti-trumpet' of 3m length with a reducing effect from 50×120 mm^2 (h × v) to 50×100 mm^2 is taken into account.

3.2 Doubly Curved Monochromator

One could think of an IN6 type of spectrometer [2, 3] consisting of a series of horizontally flat monochromators placed one behind each other, the first one being located directly at the end of the guide. Each monochromator projects adjacent wavelength bands upon the sample. This configuration is not the most suited one at SINQ since the high critical angles of the NiTi super-mirrors have detrimental effects on both the energy resolution and the intensity.

Doubly focussing monochromators with both horizontally and vertically variable curvature have been working successfully at the Laboratory for Neutron Scattering, PSI for ten years on triple axis spectrometers [7, 8]. They consist of an assembly of small individual single crystal pieces. The focussing curve is approximated by a two-dimensional polygon surface. One reason for its use on FOCUS is to increase the intensity at the sample position by space focussing the beam on the sample. In terms of a horizontal cut Figure 5 presents a schematic drawing of the individual spectrometer components with special attention on the focussing principle. Here, g denotes the neutron guide, p the pre-selector chopper, f the Fermi-chopper, m the monochromator, and s the sample. One recognizes the beam divergencies γ_0 and γ_1 in front of and behind the monochromator with γ_0 defining the beam size at the monochromator position. Due to the fact that the monochromator consists of several single crystal pieces the smallest achievable monochromator contribution to the energy resolution is not given by the beam divergence but by the local divergencies per crystal piece α_0 and α_1. The large number of crystal pieces then increases the intensity without loss of energy resolution.

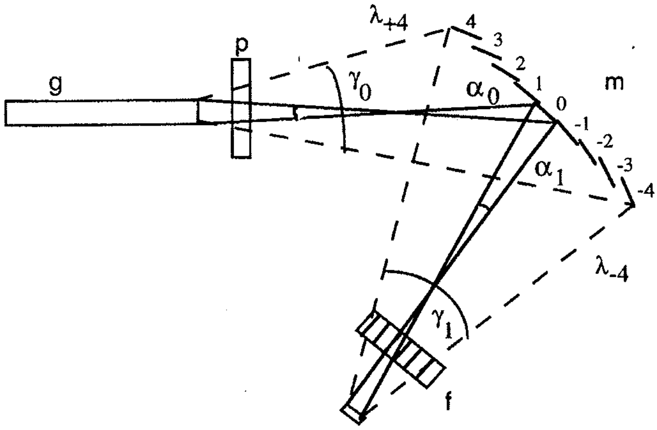

FIGURE 5 Horizontal cut through the main spectrometer components guide g, pre-selector chopper p, monochromator m, Fermi-chopper f. The sample is denoted by s. The monochromator consists of several individual single crystal pieces. γ_0 denotes the beam divergency, whereas α_0 is the local divergency per crystal piece.

Focussing can be easily achieved in the vertical direction, since the beam height is large enough. In this case the vertical radius of curvature R_v of the monochromator is given by:

$$R_v = 2 \cdot f \cdot \sin\theta \tag{1}$$

where f is the focal length and θ is the Bragg angle.

Horizontal focussing, just at the end of the guide is more complicated since the width there is at most 5 cm. The horizontal radius of curvature R_h reads [9]:

$$R_h = 2 \cdot f / \sin\theta \tag{2}$$

The wavelength uncertainty $d\lambda/\lambda$ of the monochromator is proportional to the uncertainty of the Bragg angle $d\theta$ of each single crystal piece:

$$d\lambda/\lambda = \cot(\theta)d\theta \tag{3}$$

where $d\theta$ is given by [10, 11]:

$$(d\theta)^2 = \frac{\alpha_0^2\eta^2 + \alpha_1^2\eta^2 + \alpha_0^2\alpha_1^2}{\alpha_0^2 + \alpha_1^2 + 4\eta^2} \tag{4}$$

η denotes the mosaicity of the crystal piece. Figure 6 shows $d\theta$ as a function of α_0. η and α_1 are both chosen to be 0.8°. One recognises that especially for small values of α_0 the resolution is very sensitive to slight variations of the local divergence.

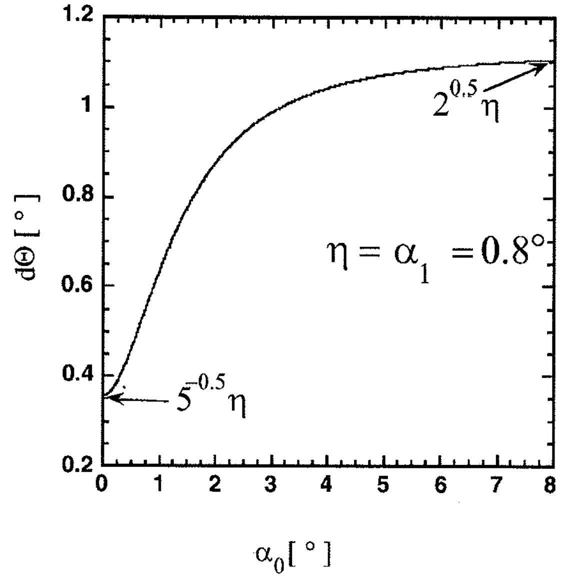

FIGURE 6 Uncertainty of Bragg-angle per crystal piece $d\theta$ as a function of the local divergence in front of the monochromator (primary divergence) α_0 for a fixed setting of mosaicity η and secondary divergence α_1 (eq. 6). One recognises the strong dependence on α_0 especially for small values of α_0.

The proposed solution for FOCUS therefore consists in an increase of the distance guide-monochromator to minimise the relatively high divergence obtained just at the end of the super mirror guide.

The width, W_m, and the height, H_m, of the monochromator are defined as follows:

$$W_m = W_g + \gamma_0 \cdot L_{gm}/\sin(\theta) \tag{5}$$

$$H_m = H_g + \gamma_0 \cdot L_{gm} \tag{6}$$

Thus, the monochromator will approximately be of the dimensions 20 × 20 cm^2 using pyrolithic graphite. Therefore with a reasonable size of the monochromator horizontal focussing is realisable.

3.3 Graphite and Mica Crystals

Due to the high critical angle and the curvature of the guide, a wavelength band from approximately 1.5Å to 20 Å will be accessible at the spectrometer position (see Figure 3). Using a graphite monochromator (d = 3.355 Å), a take-off angle $35° \leq 2\theta \leq 140°$, and the pre-selector chopper (see Section 3.5) the incident wavelengths cover the following bands:

hkl	λ(Å)	E(meV)
002	2.0 – 6.3	20.5 – 2.0
004	λmin – 3.2	*Emax* – 8.0

Here, we use $\lambda_{\min}$ and $E_{\max}$ instead of fixed values due to the fact that the initial spectrum within our guide has just been simulated up to now.

Recently, Mica analysers have been installed on the inverted TOF spectrometer IRIS at ISIS [12]. Mica is perfectly suitable for long wavelengths since it may have d-spacings up to 9.9Å. Again using 002, 004 reflections we could have access to the following incident wavelength bands:

hkl	λ(Å)	E(meV)
002	6.0–18.6	2.3–0.24
004	3.0–9.3	9.1–0.95

Thus, the incident wavelength can be continuously varied from a value between 1.5 and 2Å up to 18.6 Å. The use of higher order reflections allows to work at higher take-off angles, which means an improvement of the energy resolution.

3.4 Fermi-Chopper

The wavelength band delivered by a curved monochromator is given in first approximation by [13]

$$\Delta\lambda_m = (\lambda_i/2) \cdot \cot(\theta)|\gamma_1 - \gamma_0| \tag{7}$$

For triple-axis spectrometers, the conditions are chosen to reach monochromatic focussing, i.e., $\gamma_1 = \gamma_0$, or $L_{gm} = L_{ms}$. The situation might be different in the case of a TOF spectrometer. The Fermi-chopper positioned between the monochromator and the sample creates a delay time ΔT between the first and last neutrons passing through it:

$$\Delta T = \gamma_1 / 2\pi\nu \tag{8}$$

with the rotating frequency ν. This contribution has of course a detrimental effect on the energy resolution. There are two ways to reduce it:

3.4.1 Time Focussing

The uncertainty ΔT can be removed or at least be reduced by the time (or angle) focussing principle: the Fermi-chopper allows the slow neutrons to start before the fast ones in such a way that they will reach the detectors simultaneously. Therefore one recognises immediately the need for non-monochromatic focussing. This is achieved by choosing non-equal distances L_{gm} and L_{ms}. Using the relation $\gamma_0/\gamma_1 = L_{gm}/L_{ms}$, one yields the focal condition for the Fermi-chopper frequency:

$$\nu = \left((1 - L_{ms}/L_{gm}) \left(L_{cs} + L_{sd} \left(\frac{\lambda_f}{\lambda_i} \right)^3 \right) \cdot \pi \cdot C \cdot \lambda_i \cdot \cot\theta \right)^{-1} \tag{9}$$

with C = 252.78 μs/Å/m. A disadvantage of the time focussing is the poor energy resolution out of the focussing conditions. In other words the resolution is good over a small energy interval only (solid line in Figure 7).

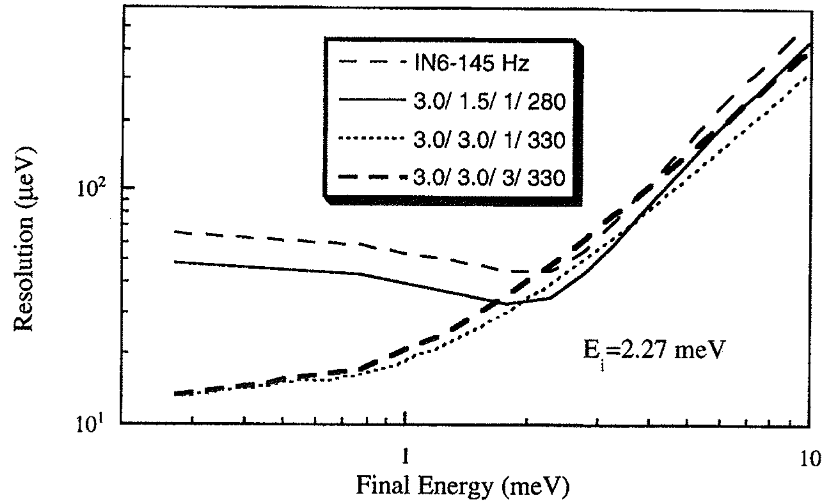

FIGURE 7 Calculated (MC simulation) energy resolution as a function of the final neutron energy E_f for IN6 at ILL and three different settings of FOCUS. The parameters correspond to $L_{gm}/L_{ms}/\Sigma[\mathrm{deg}]/\nu[\mathrm{Hz}]$. All other parameters are given in Table 1.

3.4.2 Monochromatic Focussing

If one desires a good resolution over a wide range of energy transfers, it is necessary to focus monochromatically. For that purpose the distances L_{gm} and L_{ms} have to be equal. In order to minimise ΔT the Fermi-chopper has to speed at maximum velocity. Two extreme configurations are envisaged:

- $L_{gm} = L_{ms}$ = 1.5 m by adding a 1.5 m guide between the disc-chopper and the monochromator. Thus an elongation of the neutron guide is achieved and the source is being moved forth into the direction of the monochromator. In that case the intensity is high, but the resolution is low due to the relatively high local divergence.
- $L_{gm} = L_{ms}$ = 3 m by increasing the distance monochromator-sample and removing the additional guide between the first chopper and the monochromator. In that case the intensity is low but the resolution is high since the collimation of the beam is small.

A Monte Carlo based calculation of the energy resolution of FOCUS at different spectrometer settings is presented in Figure 7 for an incident neutron energy of $E_i = 2.27meV$. One clearly recognises the qualitatively different energy transfer dependence of the resolution in the time focussing and the monochromatic focussing mode, respectively. Additionally, the energy resolution of the time focussing IN6 at the focussing chopper frequency of 145Hz is plotted to allow for a comparison with the expected FOCUS resolution. At the elastic peak position the time focussing mode of FOCUS is expected to yield a comparable energy resolution as IN6, whereas the machine in its monochromatic focussing mode will gain a factor 2-3 in ΔE for neutron energy loss scattering.

3.4.3 Chopper Collimation

In the monochromatic configuration there is no need for time (or angle) focussing and the collimation of the Fermi-chopper can be relaxed without strong detrimental effects on the resolution (bold dashed line in Figure 7). This means a large intensity gain even if the anti-overlap conditions have to be considered at high frequencies. Intensities and energy resolutions for several configurations will quantitatively be discussed in Section 4.

It is envisaged to provide different Fermi-chopper rotors with straight collimations Σ varying from (1–3)° at the final stage of the instrument. Thus, the calculations presented here have been performed both for these two extreme collimations. For the 'day 1' operation FOCUS will run under an intermediate collimation of $\Sigma = 2.4°$.

3.5 Pre-Selector Chopper

One of the major problems when using crystal monochromators is the contamination of the incident beam by unwanted diffraction order reflections.

This problem can be transformed into an advantage on a TOF spectrometer, since the use of two choppers and one crystal monochromator allows one to select only the desired wavelength or reflection. This is visualised in Figure 8. The distance between the two choppers has to be as large as possible, in order to clearly time-resolve neutrons with different energies. In the case of FOCUS the two choppers are separated by a distance ranging from (3.8–5.3)m. This is possible since the spectrometer will be located at the end position of the guide.

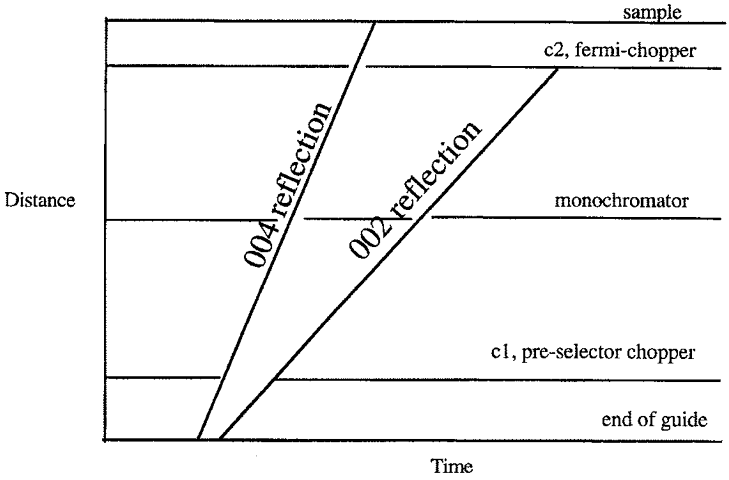

FIGURE 8 Principle of energy selection by a hybrid - TOF. The unwanted reflections can be excluded by choosing a certain setting of chopper speeds.

Of course, the pre-selector will act as anti-overlap chopper as well since it can turn in phase with the Fermi chopper but at lower speeds, i.e. frequency ratios 1:2, 1:3, 1:4, etc. The pre-selector chopper will be designed as a rotating disc-chopper with a maximum frequency of 10000 rpm. The disc will have two trapezoidal beam windows to provide a constant plateau width of the transmission function over the entire window area. In this configuration frame overlap and unwanted reflections can be removed either by using a Be-Filter if necessary and/or by a minor modification of chopper frequency or incident wavelength. Thus, we find here another argument for a continuously variable incident energy.

3.6 Banks of Detectors

The detector bank will be located at a distance $L_{sd} = 2.5$ m from the sample and will cover an angle range from -34° to -10° and +10° to +130°. Table 2 collects the values for the maximum scattering vector Q^m at the elastic peak position obtainable by such a range of scattering angles.

TABLE II Obtainable values for the maximum scattering vector Q^m for several incident energies.

λ[Å]	18.1	9.0	6.0	4.0	2.0
E_i [meV]	0.25	1.0	2.3	5.1	20
Q^mÅ^{-1}]	0.6	1.3	1.9	2.8	5.6

In a first step, the spectrometer housing will contain one row of 200 quenched ^{3}He detectors with rectangular cross section of 1cm depth and 3cm width. Thus, it is possible to cover the total solid angle of 164° with 200 counter tubes by keeping approximately the time resolution of a counter tube with circular cross section of 1cm diameter. The active length of each counter tube will be 40 cm. FOCUS will have the option for two additional banks of detectors such that the spectrometer will run on 600 counter tubes in its final stage.

4 PERFORMANCE

Intensity and energy resolution have been calculated for the proposed spectrometer as well as for IN6-type spectrometers (IN6 at ILL and IN6 at SINQ). We used either the equations developed by Mutka *et al.* [13, 14] or a modified version of a Monte Carlo simulation program developed by the same author [15]. The results obtained using both methods are very similar as shown in Figure 9. Here, the monochromator is assumed as a two dimensional polygon surface. The dynamical transmission of the Fermi-chopper is also taken into account. The differences occurring away from the focussing point are due to the assumed Gaussian divergence distributions for the analytical expressions, whereas the simulation starts from the calculated divergence distributions as given in Figure 4. The calculated resolutions of IN6-ILL at the focussing points (176 μeV at 4 Å and 45 μeV at 6 Å) are in excellent agreement with the observed ones (170 μeV and 50 μeV) [2].

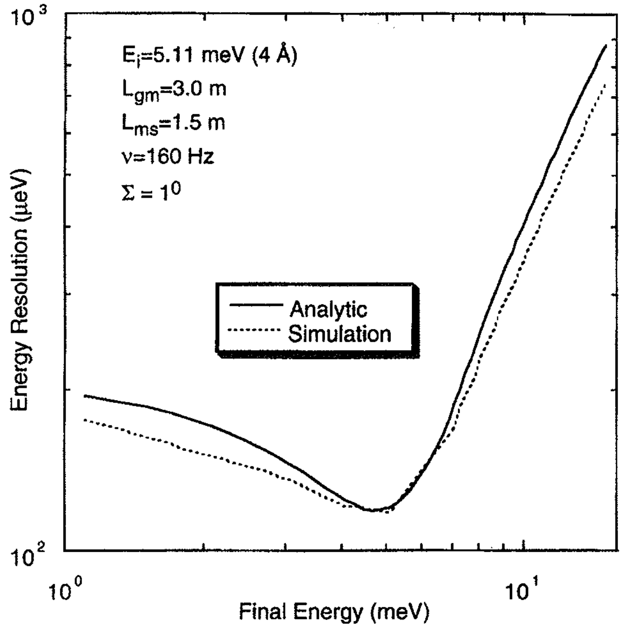

FIGURE 9 Energy resolution as a function of final energy for the time focussing geometry at FOCUS using the PG 002 reflection at an initial energy of 5.11 meV. The dashed line represents the MC simulation, whereas the solid line is obtained by analytical calculation based on [14, 15].

Table 3 summarises the intensities and resolutions calculated for several wavelengths and instrumental configurations of FOCUS at 6 Å initial wavelength (PG002). The results obtained for IN6-ILL and an IN6-type spectrometer at the SINQ (IN6-SINQ) are also given. The relevant parameters are the distances L_{gm}, L_{ms}, the chopper frequency ν, and the Fermi chopper collimation Σ. All other parameters are taken from Table 1 or from the existing IN6-ILL. We included in our intensity calculations an anti-overlap condition for Fermi-chopper frequencies higher than 160 Hz. The flux $\partial\sigma/\partial\lambda$ has been set equal to unity. The first Zircalloy Rod Target should deliver a flux of the order of one third of the flux measured at the ING-ILL guide. The next generation target should allow to increase the flux by a factor 3. Within the table, all intensities are given relative to the instrument configuration indicated in the first row. It should be emphasized that the results remain qualitatively valid at all wavelengths.

TABLE III Calculated performance(energy resolution, intensity) of FOCUS for its different settings at the elastic line and two inelastic energy transfers, respectively for an initial wavelength of 6Å (PG002). The intensities are normalised to the first row of the table. Additionally, the corresponding values for the original IN6 at the ILL and an IN6-type of spectrometer at a SINQ guide are included.

	$\lambda = 6$Å Instr. Type	Intensity analytic	Resolution $\Delta E = -2$ meV	Resolution $\Delta E = 0$ meV	Resolution $\Delta E = 10$ meV	Comments
				PG002		
IN6-ILL		(μeV)	(μeV)	(μeV)		
1	145 Hz	1.00	66	45	850	Time-foc.
2	330 Hz	0.29	67	59	400	
	IN6-SINQ					
3	145Hz	0.72	71	55	870	Time-foc.
4	330Hz	0.21	73	67	400	
	FOCUS					
	L_{gm}/ L_{ms}/ Σ/v					
5	3.0/ 1.5/ 1/ 160	0.67	46	54	1140	
6	3.0/ 1.5/ 1/ 280	0.26	47	35	690	Time-foc.
7	1.5/ 1.5/ 1/ 160	0.49	23	63	770	Monochr.
8	1.5/ 1.5/ 1/ 330	0.15	23	46	460	Monochr.
9	3.0/ 3.0/ 1/ 160	0.24	13	59	740	Monochr.
10	3.0/ 3.0/ 1/ 330	0.07	13	38	450	Monochr.
11	1.5/ 1.5/ 3/ 160	1.82	26	85	1060	Monochr.
12	1.5/ 1.5/ 3/ 330	0.87	26	47	580	Monochr.
13	3.0/ 3.0/ 3/ 160	0.86	13	84	1050	Monochr.
14	3.0/ 3.0/ 3/ 330	0.42	13	46	580	Monochr.

For comparable resolutions at the focussing point, FOCUS (row 12 (R12)) will reach almost 90% of the intensity of IN6-ILL (R1).

At large energy transfer the resolution of FOCUS (even in the time-focussing mode, R6) is even better than the one of IN6-ILL. Of course one can think of increasing the speed of the IN6-ILL chopper (R2) and using only one monochromator, at the expense, however of intensity.

On the other hand an IN6-SINQ spectrometer (R3) would have about 70% of the intensity of IN6-ILL, but with a worse resolution at all energy transfers.

The monochromatic configurations (R7–14) of FOCUS are the most attractive ones since it is possible to increase the intensity by almost a factor 4 (R11/R7) just by relaxing the chopper collimation from 1° to 3°.

Note that in the extreme case of short distances, large collimation and low frequency (R11) the calculated flux is more than 80 % higher on FOCUS than on IN6-ILL. On the other side, a 1° collimation combined with the highest frequency and largest distances gives an excellent resolution over the whole energy-transfer range (R10).

The use of large chopper collimations in connection with high frequencies is even more advantageous at larger wavelengths since, in comparison with the time-focussing mode, at almost equal intensity the resolution is better over the whole energy range. This is due to the very low dynamical transmission of the Fermi-chopper at such large wavelengths as shown in [3]. At 18 Å, the transmission function (1° collimation) is zero down to 230 Hz, such that we are forced to use a 3° collimation. Another alternative would be the use of a curved collimator.

Table 4 compares intensity and energy resolution for the time-focussing (R1) and two monochromatic focussing configurations (R2,R3) of FOCUS at an initial wavelength of 9Å and the Mica002 reflection. Again the attractiveness of the monochromatic configuration is obvious. At comparable intensity to the time-focussing mode (R3,R1) a good energy resolution is obtained at all energy transfers, whereas for the short distances (R2) a factor 2.5 in intensity is gained at the expense of loosing a factor 3 in the energy resolution at the elastic peak position.

TABLE IV Calculated relative intensity and energy resolution of FOCUS for 9Å (Mica002) at different spectrometer settings.

	λ = 9Å Instr. Type	Intensity analytic	Resolution $\Delta E = -1$ meV	Resolution $\Delta E = 0$ meV	Resolution $\Delta E = 3$ meV	Comments
	FOCUS			**MICA**	**002**	
	L_{gm}/ L_{ms}/ Σ/v		(μeV)	(μeV)	(μeV)	
1	3.0/ 1.5/ 1/ 47	1.00	121	32	840	Time-foc.
2	1.5/ 1.5/ 3/ 47	2.49	37	102	760	Monochr.
3	3.0/ 3.0/ 3/ 330	1.00	18	28	160	Monochr.

It is taken into account to use also the 004 reflections of the PG and the Mica monochromators with the advantage of larger take-off angles such that the energy resolution gets further increased.

5 CONCLUSIONS

The physical design of the new hybrid TOF-spectrometer FOCUS for cold neutrons at the Swiss spallation neutron source SINQ has been presented. The spectrometer will focus the beam in space and time by using a doubly curved monochromator combined with a Fermi-chopper. It has been shown that a direct IN6-copy at SINQ is not the most appropriate solution due to the high divergence of the supermirror guide. Furthermore, a complementary second TOF machine like IN5 will not be available so that FOCUS has to be suited for both quasielastic and inelastic applications.

By an increase of the distance guide - monochromator and the simultaneous use of a focussing monochromator a competitive and flexible TOF-spectrometer can be built.

The key parameters for the design of the instrument are the distances guide-monochromator, monochromator-sample, and Fermi-chopper collimation. Changing the configuration allows to work either in high intensity or high resolution mode.

Energy resolutions and intensities have been calculated for FOCUS using a Monte Carlo algorithm. If possible the calculated values have been compared with the experimental results obtained on IN6.

FOCUS is being built in cooperation between the 'university of Saarbrücken, Germany', the 'Paul Scherrer Institut, Switzerland', and the 'Forschungszentrum Jülich, Germany'. The main spectrometer components are presently construction expecting their completion in Winter 96/97 so that FOCUS could be at the user community's disposition in summer 97.

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