FREIA flux calculation

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The flux Φ at the sample can be calculated from the spectral source time-average brightness *B* as:

$$\Phi = B \times \Delta\Omega \times \Delta\lambda \times R \qquad (1)$$

where $\Delta\Omega$ is the source solid angle transported by the guide, $\Delta\lambda$ is the wavelength range, selected by the choppers, and *R* is the duty cycle. The duty cycle is the ratio of the opening time of a possible pulse-shaping chopper system to the pulse length of the ESS ($\Delta t/\tau$).

The source solid angle transported to the sample $\Delta\Omega$ can be approximated as simply the product of the vertical and horizontal divergence transported by the guide, assuming that the guide transport for neutrons within that divergence range is perfect. I made a crude Monte Carlo transport calculation of the FREIA guide system, modelling only the horizontal geometry, in order to estimate the horizontal divergence.

The simplified horizontal geometry of FREIA is given in Table 1.

Component	Width	Start	End	Rc	m	channels
Moderator	90 mm	0				
Bend 1	40 mm	2 m	8.5 m	-130 m	3	4: 9.8+0.2mm
Bend 2	40 mm	8.5 m	15 m	+130 m	3	4: 9.8+0.2mm
Straight guide	40 mm	15m	20m	None	3	

Table 1 FREIA guide geometry

I simulated the transport of the LOKI guide using my own Monte Carlo code with the Table 1 geometry as input. I obtained the wavelength-dependent horizontal divergence shown in Fig. 1.

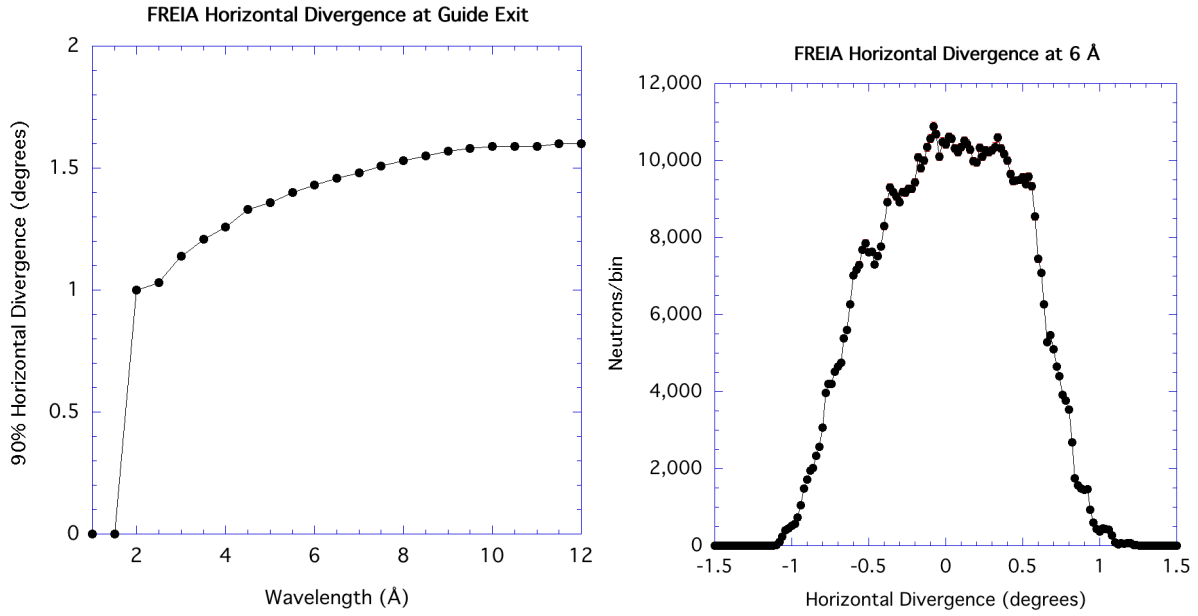

Fig. 1 Horizontal divergence at the FREIA guide exit. Left: as a function of wavelength. Right: at a wavelength of 6 Å.

A typical horizontal divergence distribution is shown in the right-hand panel of Fig. 1, corresponding to a wavelength of 6 Å. The widths shown in the left-hand panel correspond to the minimum range required in order to include 90% of the neutrons in the beam.

The vertical divergence is estimated to be 4 degrees, independent of wavelength. I can now estimate the flux at the guide exit, using equation (1), using the brightness of the cold BF1 moderator for B, and the product of the horizontal and vertical divergence at the guide exit to represent the source solid angle transported to the sample, and setting the duty cycle to 1 to correspond to the situation without WFM.

In order to compare to the data calculated by the instrument team, shown in Fig. 40 of [1], I need to multiply the resultant flux by tan(2deg) in order to estimate the equivalent flux obtained over a plane oriented at 2 deg to the beam axis, which is what is shown there. The result is shown in Fig. 2, where it is compared to the data shown in Fig. 40 of [1].

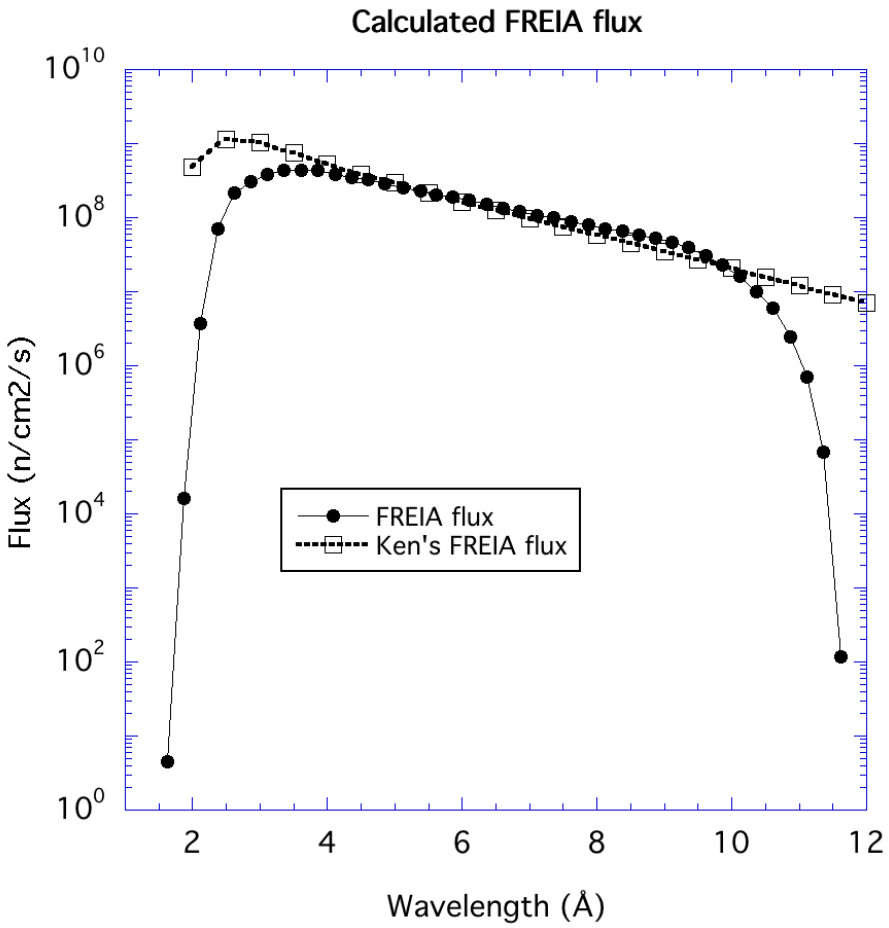

Fig. 2 calculated FREIA flux, compared to Fig. 40 of [1].

The agreement is seen to be remarkably good, considering the simplifications made.

References:

1 Preliminary System Design Description for the FREIA Instrument, ESS-0110045