Eliminating Line of Sight In Elliptic Guides Using Gravitational Curving

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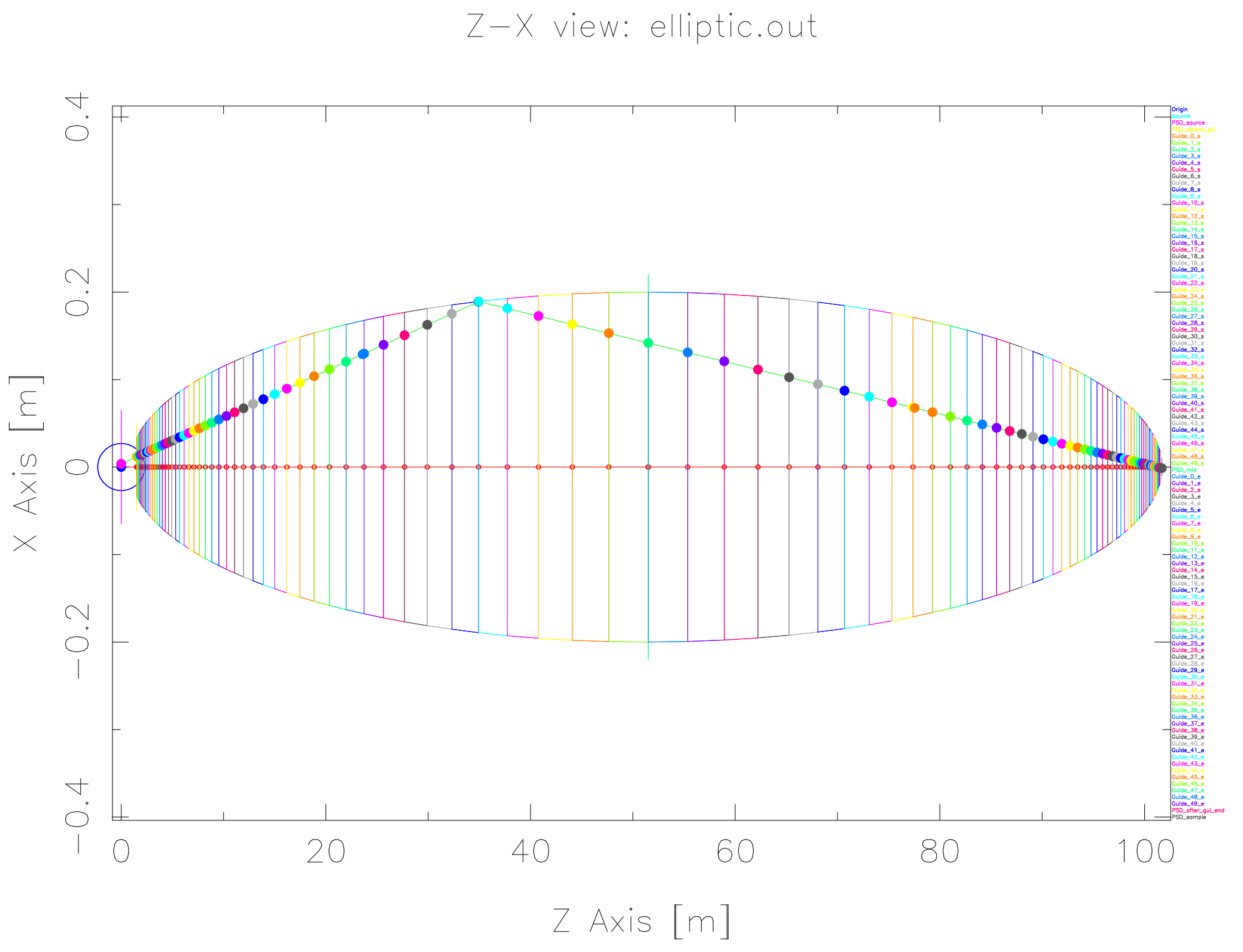
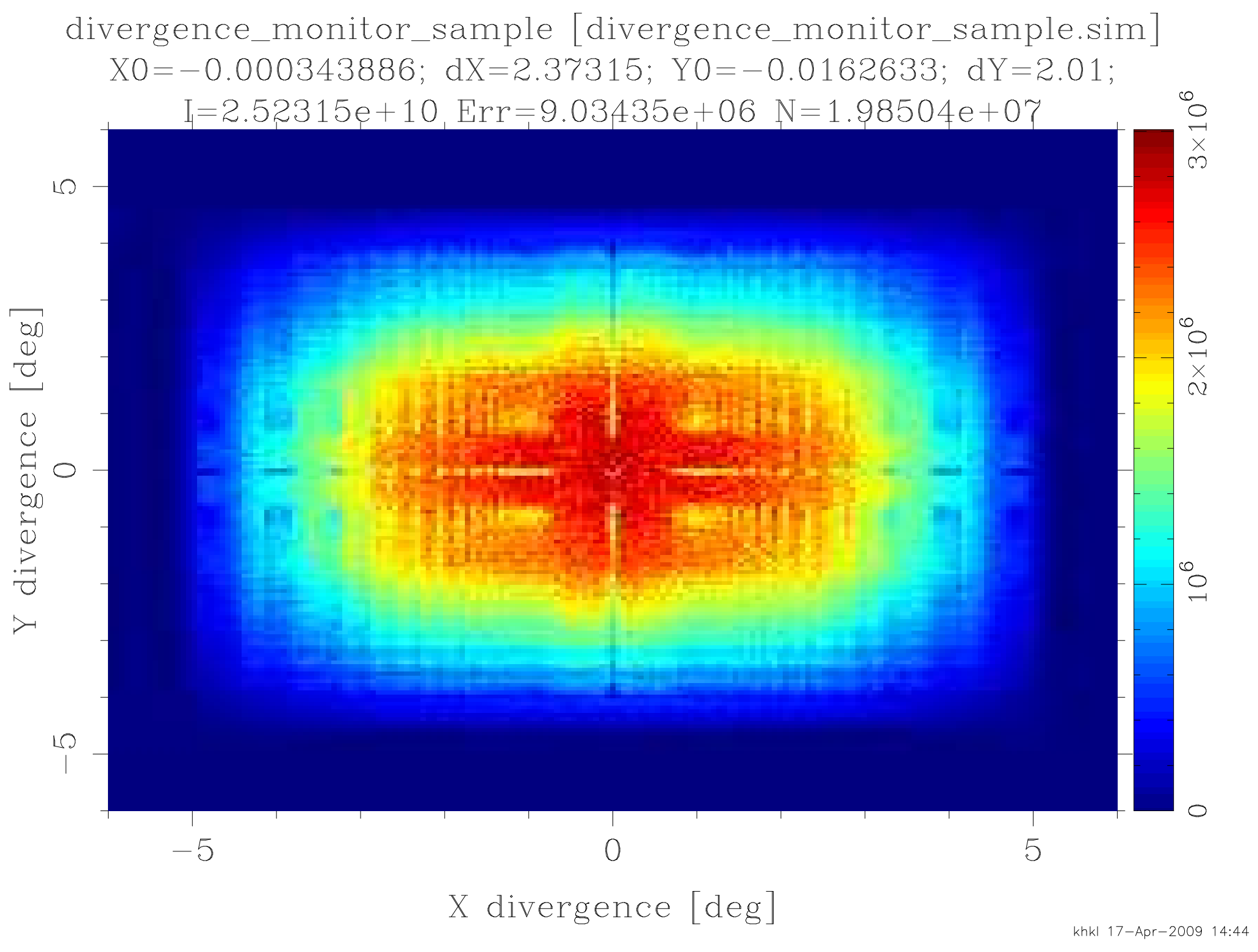
A Novel Solution to a Novel Problem

Investigating long neutron guides (100+ m) has led to the conclusion that elliptical guides are the superior solution, in terms of intensity on target. However, that still leaves the problem of blocking direct line of sight (LoS) between the moderator and the sample, so as to eliminate unwanted fast neutrons.

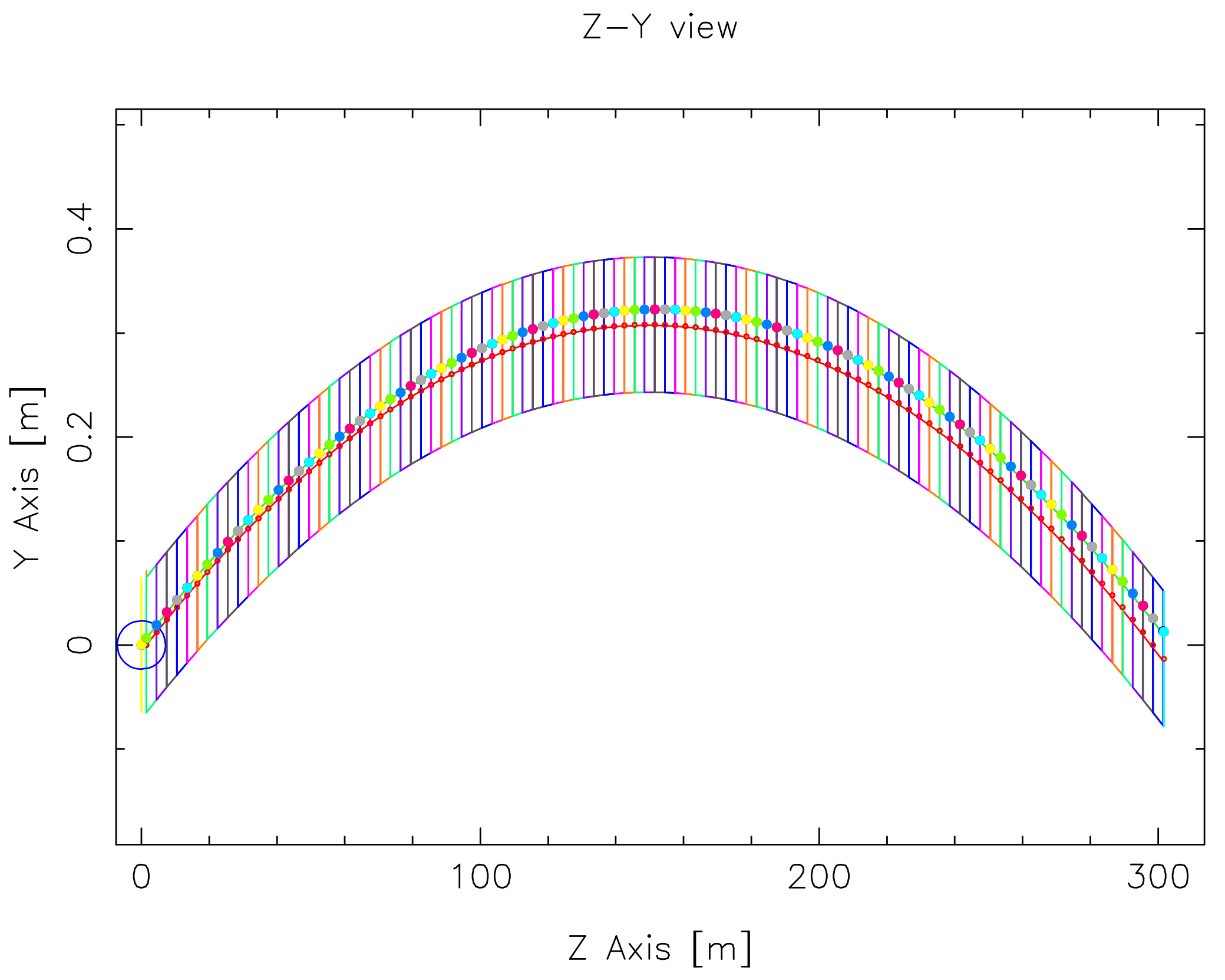


A top down view of an elliptic neutron guide, which simulations have shown offers significant advantages in transmission, over more conventional guides. The colours denotes different straight sections of guide elements, which together form an ellipse.

While an often used method to block direct LoS is to curve the guide in the horizontal plane, this would destroy the geometrical benefits of an elliptic guide. Another method is to place a beamstop in the centre of the guide. This will block LoS while have only a minimal effect on the transmission of an elliptical guide (≈ 5 %), though it does block the neutrons with the lowest divergence, which are typically the most desireable.



While a beamstop will block line of sight and effectively kill unwanted fast neutrons with very little loss in total intensity on sample, it does block the most desireable slow neutrons; those with the lowest divergence, as can be seen from the 'cross' on this divergence profile at the sample position.



Sideways view of a ballistically curved guide, composed of 100 straight sections, with a ray of the target wavelength (6.7 Å) being curved by gravity.

However, over a distance of 300 m, slow 6.7 Å neutrons will be pulled more than 60 cm down by gravity, and this can be exploited for a more elegant solution to the problem of line of sight, by curving the guide to the ballistic path of a free particle in the gravitational field. This reduces transmission of very fast 2000 meV (0.2 Å) neutrons by almost 5 orders of magnitude, while leaving the transmission of the desired 6.7 Å neutrons unchanged.

Newtonian Physics

Elementary physics tells us that if a neutron takes the time

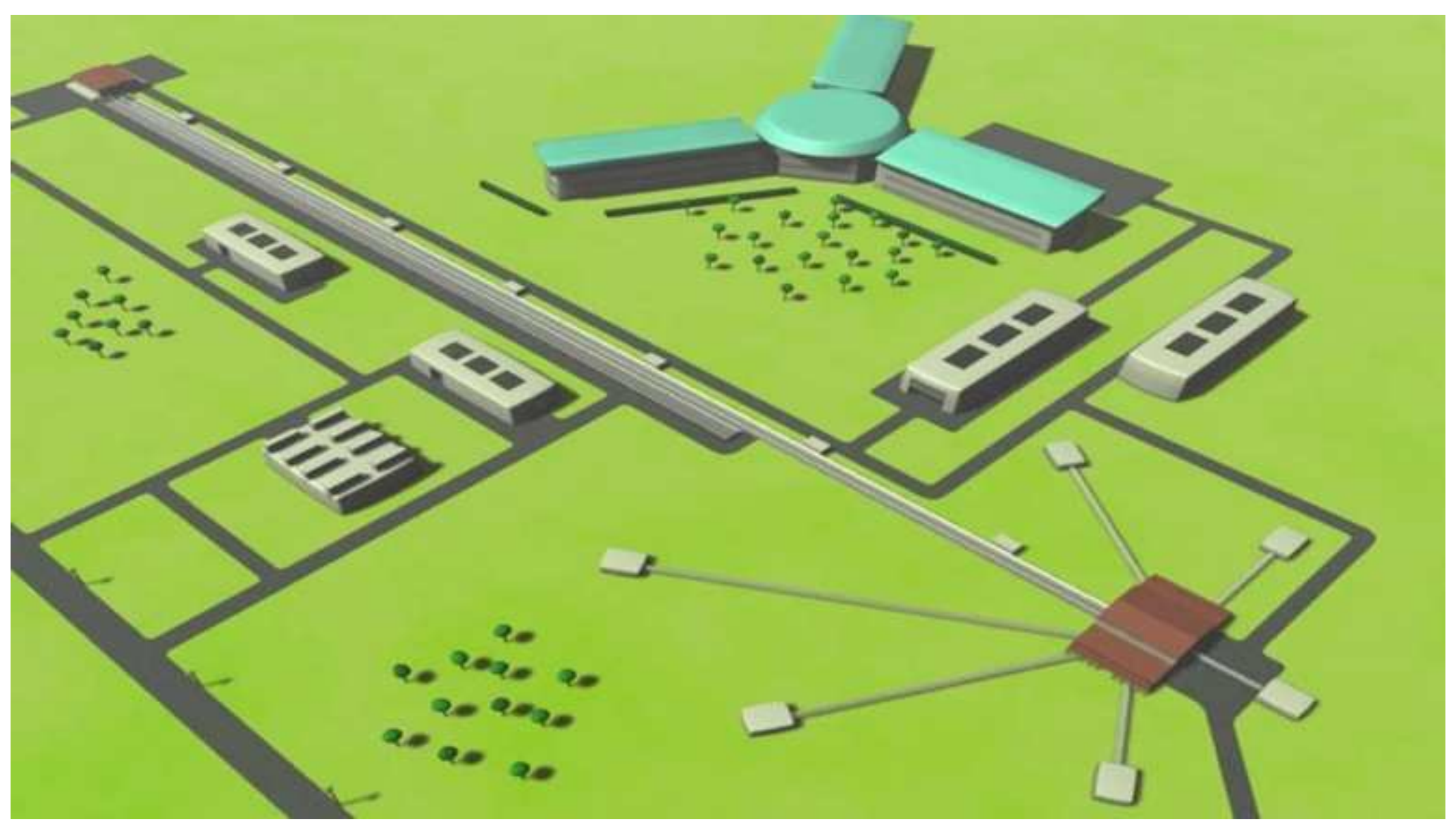
$$T = \frac{L}{v}$$

to pass through the guide, it will reach its maximum height at time $\frac{T}{2}$:

$$y_{max} = -\frac{1}{2}g(\frac{L}{2V})^2 + v\frac{L}{2V}sin(\theta)$$

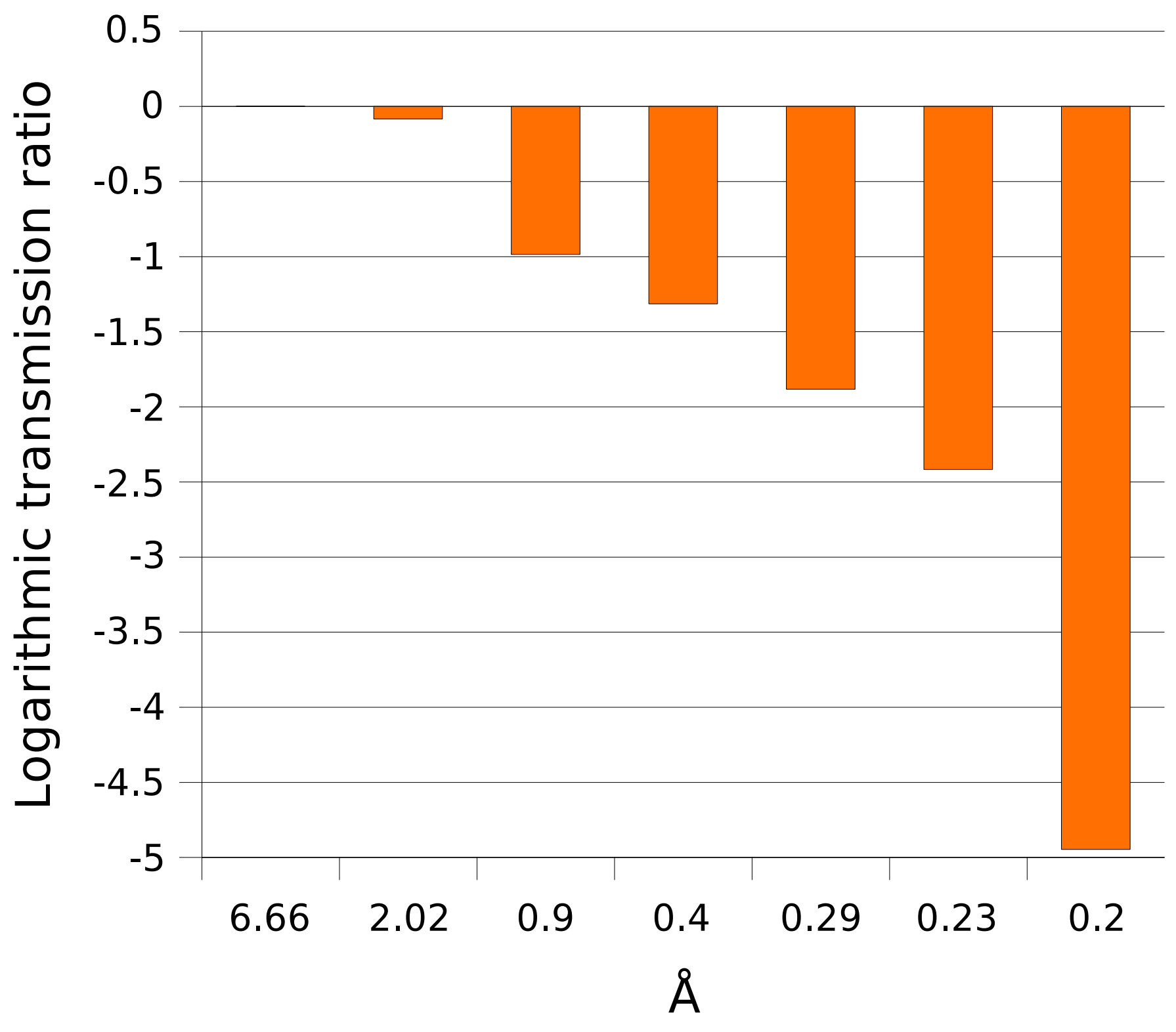
If we accept 30 cm as the minimum y_{max} that can be used to succesfully block LoS, the following table shows minimum guide lengths that can succesfully block LoS for various neutron wavelengths:

Neutron wavelength	Minimum guide length
4 Å	490 m
5 Å	390 m
6 Å	330 m
7 Å	280m
8 Å	240 m
9 Å	220 m
10 Å	200 m
15 Å	130 m
20 Å	100 m

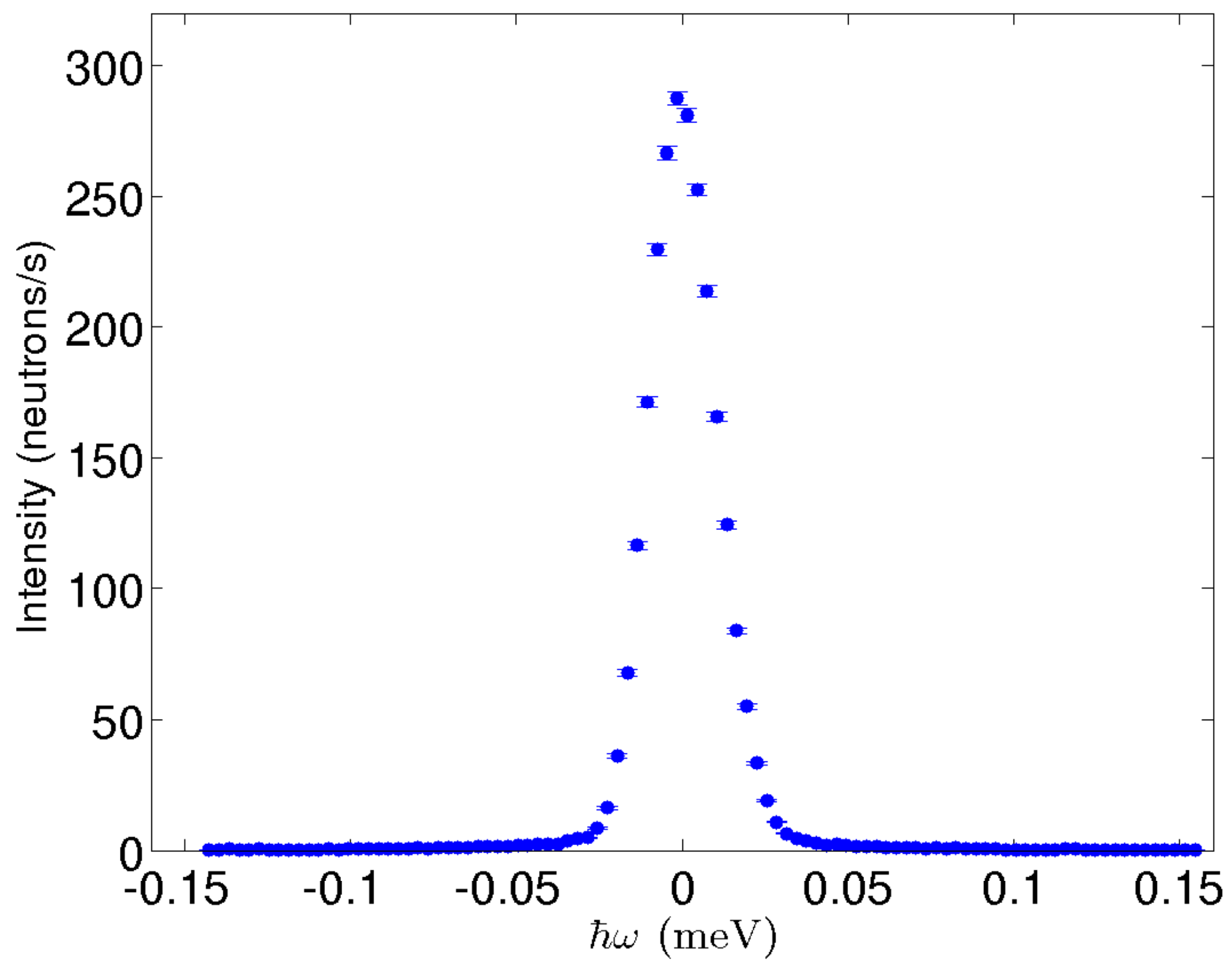


The European Spallation Source will host several instruments that take advantage of the improved resolution offered by long guides.[1]

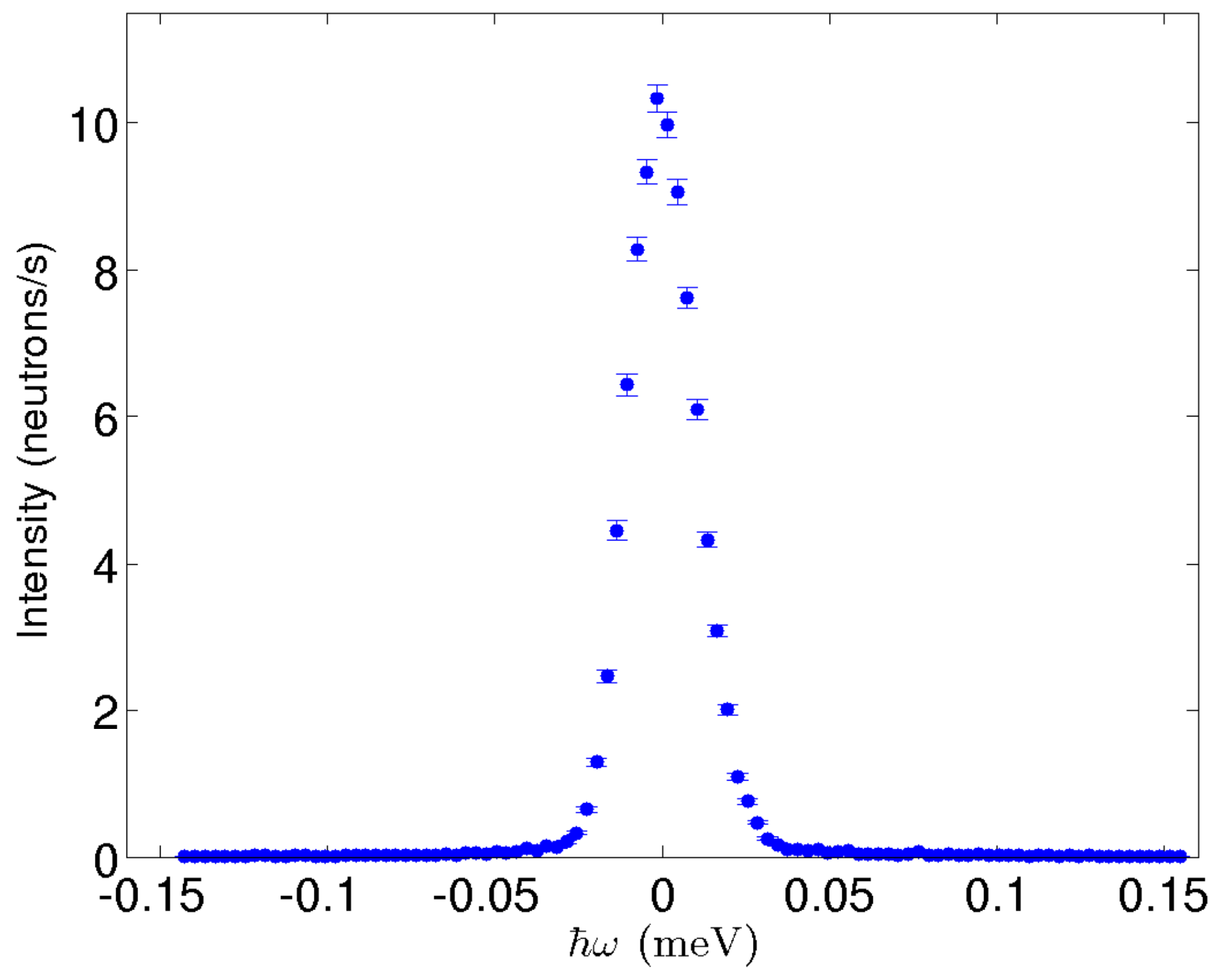
Neutron guides at the SINQ spallation source, Switzerland



The effect of curving the guide: the transmission of the desired slow neutrons is not effected, while the transmission of undesired fast neutrons is reduced by several orders of magnitude.



A virtual experiment: The energy percieved by the detector, after scattering off a sample. The zero of energy is the target wavelength which the guide is curved after.



The same as above, but now using a simple straight guide. It can be seen that while the intensity is now much lower, the instrument resolution remains unchanged. This indicates that neither the elliptical geometry nor gravitational curving has any detrimental effect on the resolution.

Conclusion

While the hefty demand guide on the length means that gravitational curving is unfeasible for most neutron instruments, it is a simple and effective solution to blocking direct line of sight for some instruments, and has none of the negative effects associated with more common methods, such as reduced intensity and increased divergence.

The guide will however be "hardcoded" for use with only one specific neutron wavelength, but that will typically be the case anyway with a backscattering instrument.

References

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