Neutron Spin Echo with colder neutrons

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Very Cold and Ultra Cold source @ ESS workshop 2022

Outline

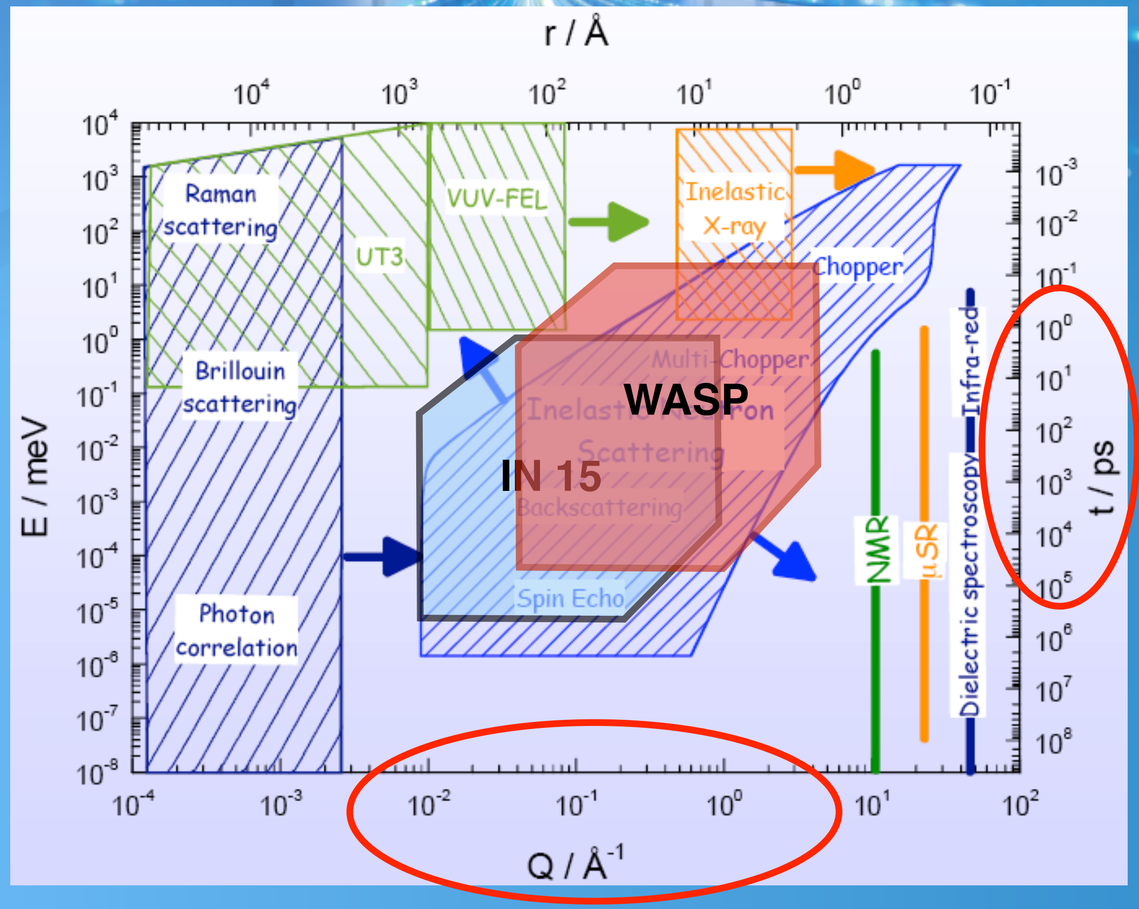
- Why am I here ?
- What is Neutron Spin Echo ?
- What are the cold source needs of NSE ?

Why talk about NSE at a VCN workshop

- NSE uses the long end of cold neutrons
- ESS Capability gap document: *The particle physics community is not at all addressed within the current 15 instruments, while the addition of a spin-echo instrument will greatly increase the kinematic coverage of the ESS spectrometer suite.*

Confirmed by Andreas!

Why NSE important



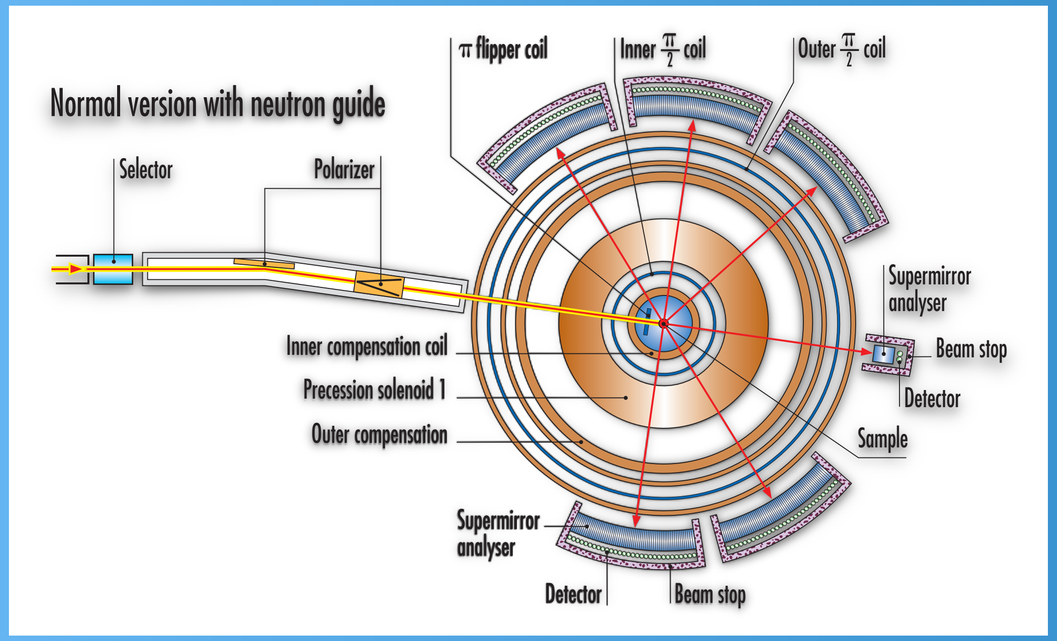
- Unmatched Q-t range
- Works in time space not energy space
- Sees difference not sum of coherent and incoherent scattering
- For magnetism XYZ polarisation analysis built in

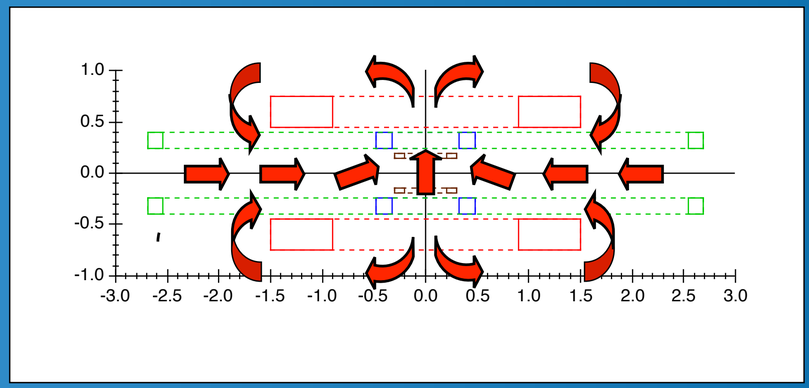
- **WASP** is optimized for **atomic to molecular length scales 0.1-4 Å^{-1}, 0.2 ps-100 ns**

- **IN 15** is optimized for **molecular length scales 0.01-1 Å^{-1}, 5ps-1000 ns**

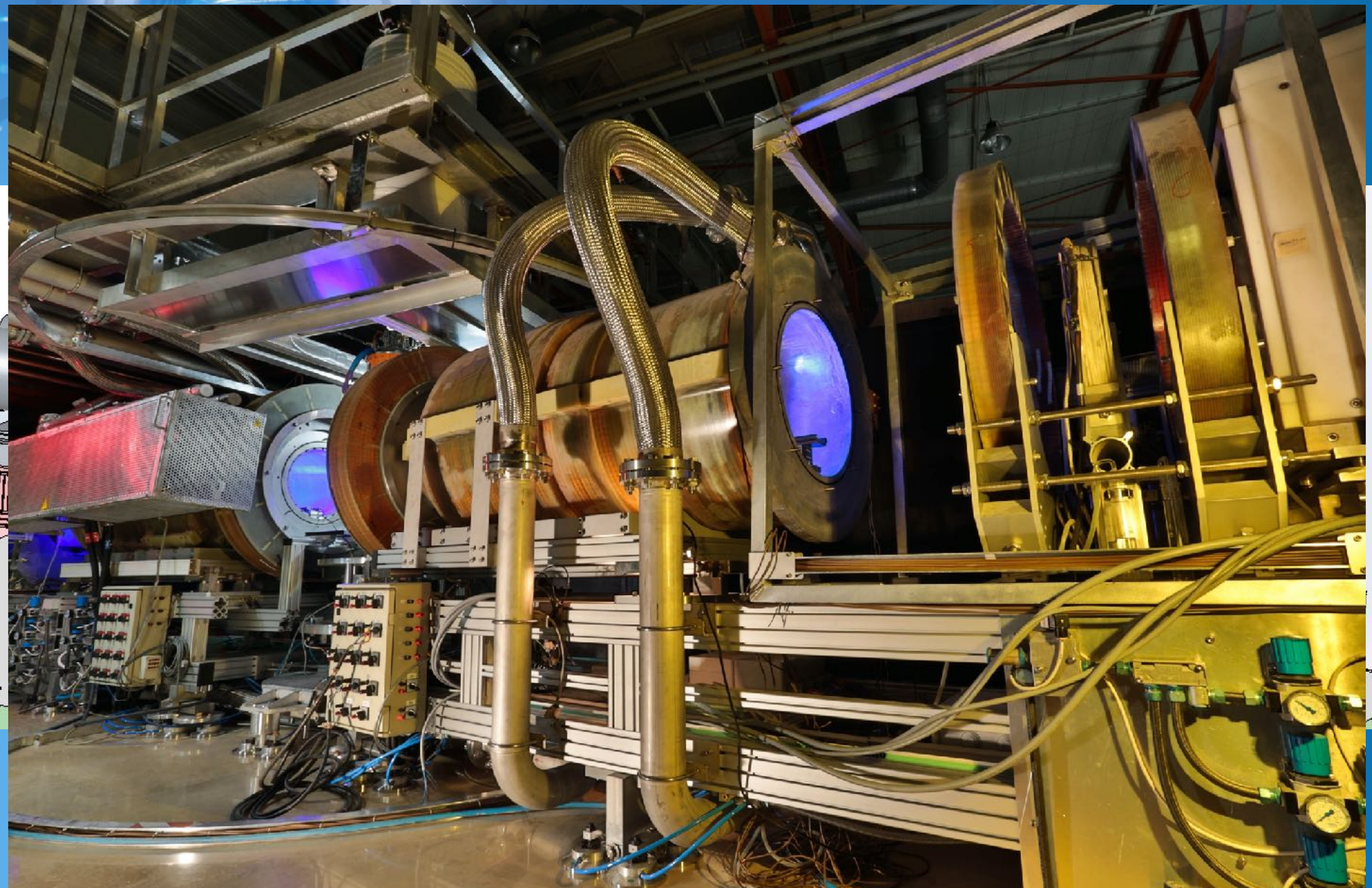
WASP 2018

SPAN





IN15 2016



EVA-SERGIS 2005

NSE science

Soft matter

Polymers melts
Filled polymers
confined Liquids
ionic liquids
lipid membranes
emulsions

Magnetism

Frustrated magnets
Spin glasses
Skyrmions

Life sciences

small biomolecules
enzymes
Monoclonal Antibodies
intrinsicly disordered proteins

Energy materials

Li battery electrolytes
fuel cells

NSE basics

Echo condition:

$$\int_{\pi/2}^{\pi} B_1 d\ell = \int_{\pi}^{\pi/2} B_2 d\ell$$

The measured quantity is: S(q,t)/S(q,0) where

$$t \propto \lambda^3 \int B d\ell$$

For elastic scattering: $\varphi_{tot} = \frac{\gamma B_1 l_1}{v_1} - \frac{\gamma B_2 l_2}{v_2} = 0$

For omega energy exchange: $\varphi_{tot} = \frac{\hbar \gamma B l}{m v^3}\omega + o\left(\left(\frac{\omega}{1/2 m v^2}\right)^2\right)$

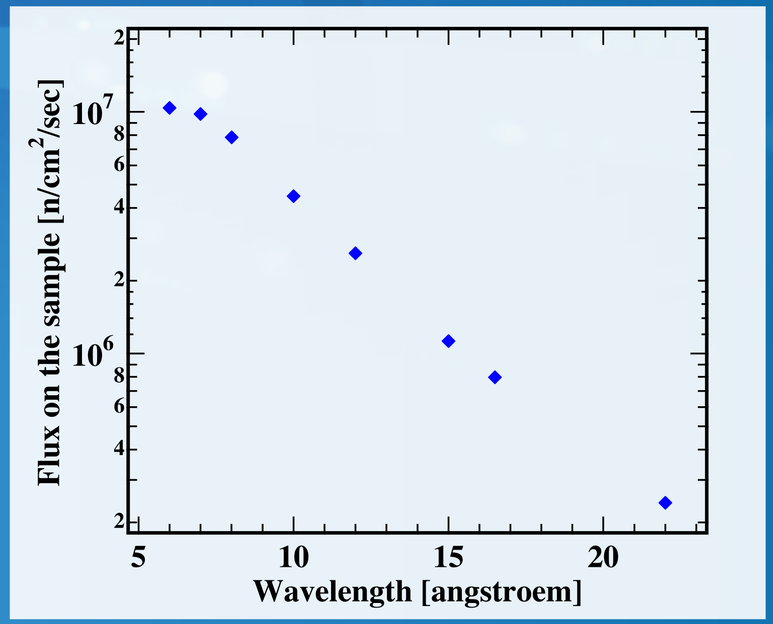
The probability of omega energy exchange: $S(q,\omega)$

The final polarization: $\langle \cos\varphi \rangle = \frac{\int \cos(\frac{\hbar \gamma B l}{m v^3}\omega) S(q,\omega) d\omega}{\int S(q,\omega) d\omega} = S(q,t)$

Long wavelengths: Source intensity

$$t \propto \lambda^3 \int B\, dl$$

$$I \propto \lambda^{-5}$$



t_{max} not decoupled from intensity !

4 x higher field integral

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1/1.6 x shorter wavelength

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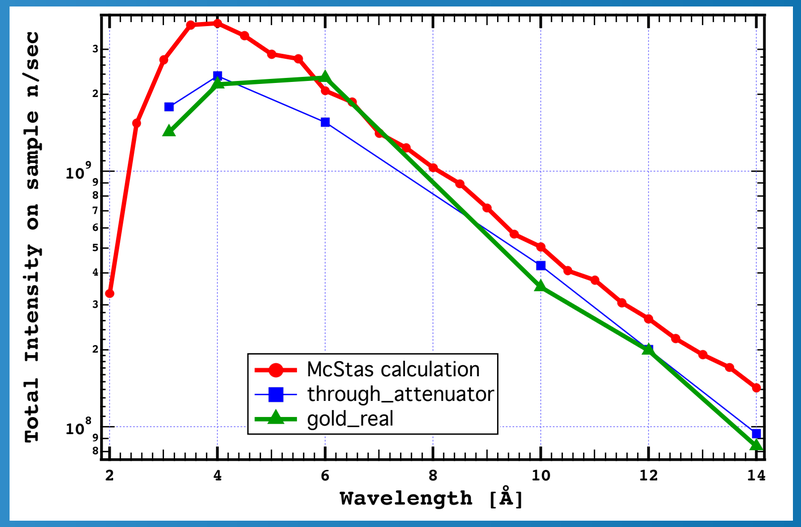
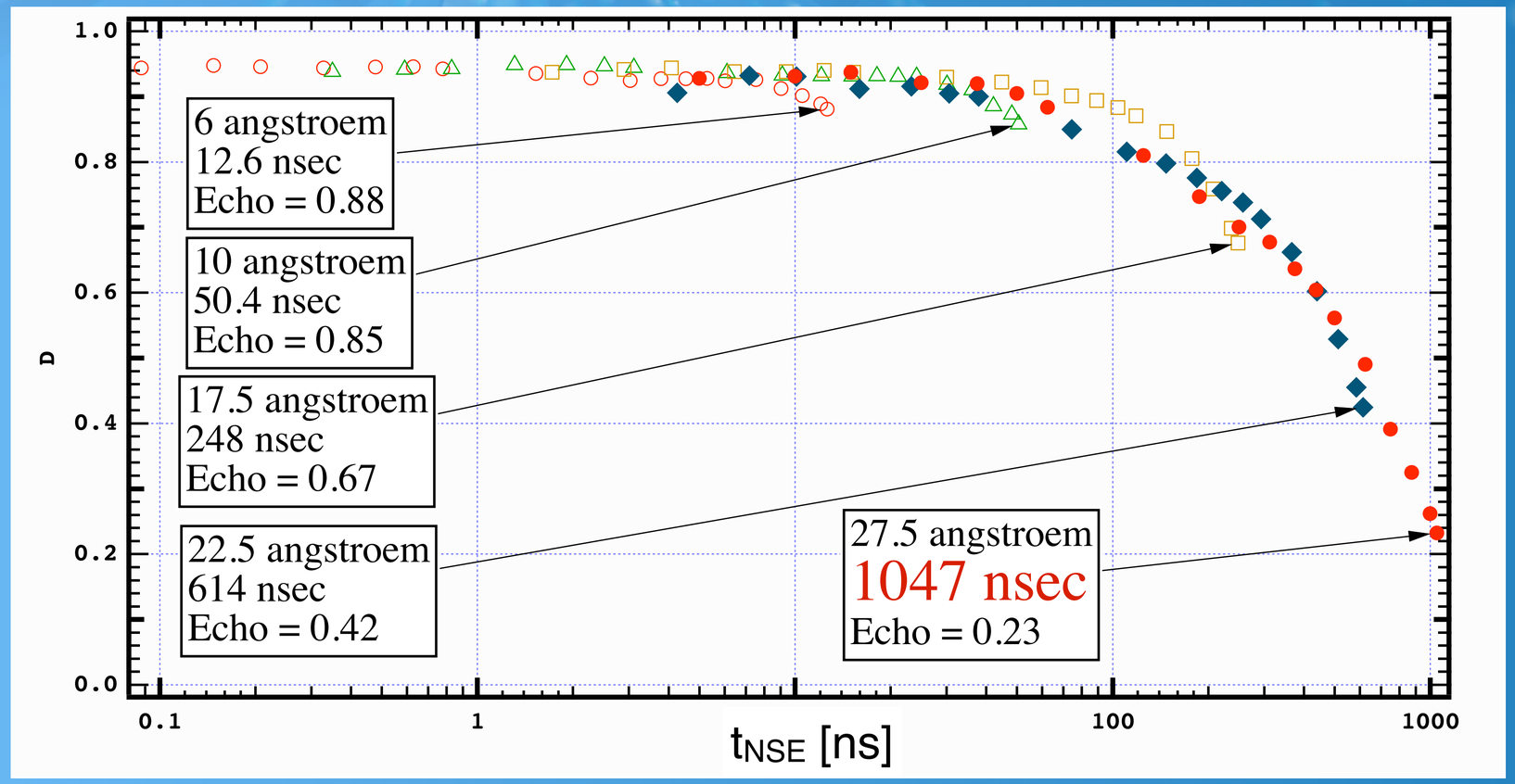
10 x higher intensity!



Long wavelength: phase difference

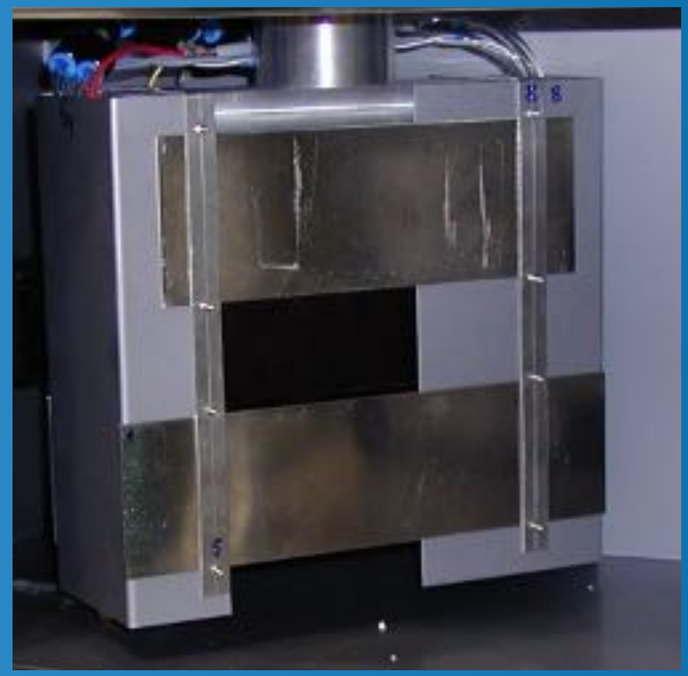
$$\varphi_{tot} = \frac{\gamma B_1 l_1}{v_1} - \frac{\gamma B_2 l_2}{v_2}$$



In practice the resolution hits a wall

Long wavelength: Flippers Fresnels in beam

cm-s alu, mm-s copper attenuation, small angle scattering



NSE source wishlist

- Wavelength IN15,SERGIS: 6-25 Å
- Wavelength WASP 3-14Å needs short wl. for high Q!
- No need for collimation but focusing difficult, guide should* stop 2m from sample
- Intensity, intensity, intensity not brightness
- Do away with Maxwell Boltzmann
- Give polarised neutrons (from the source if possible)

Acknowledgments