High wave vector magnons in ultrathin Fe/W(110) films

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SPINSWITCH

S P↓N S W↑T C H Workshop
„Spin Momentum Transfer"
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AGH

Outline

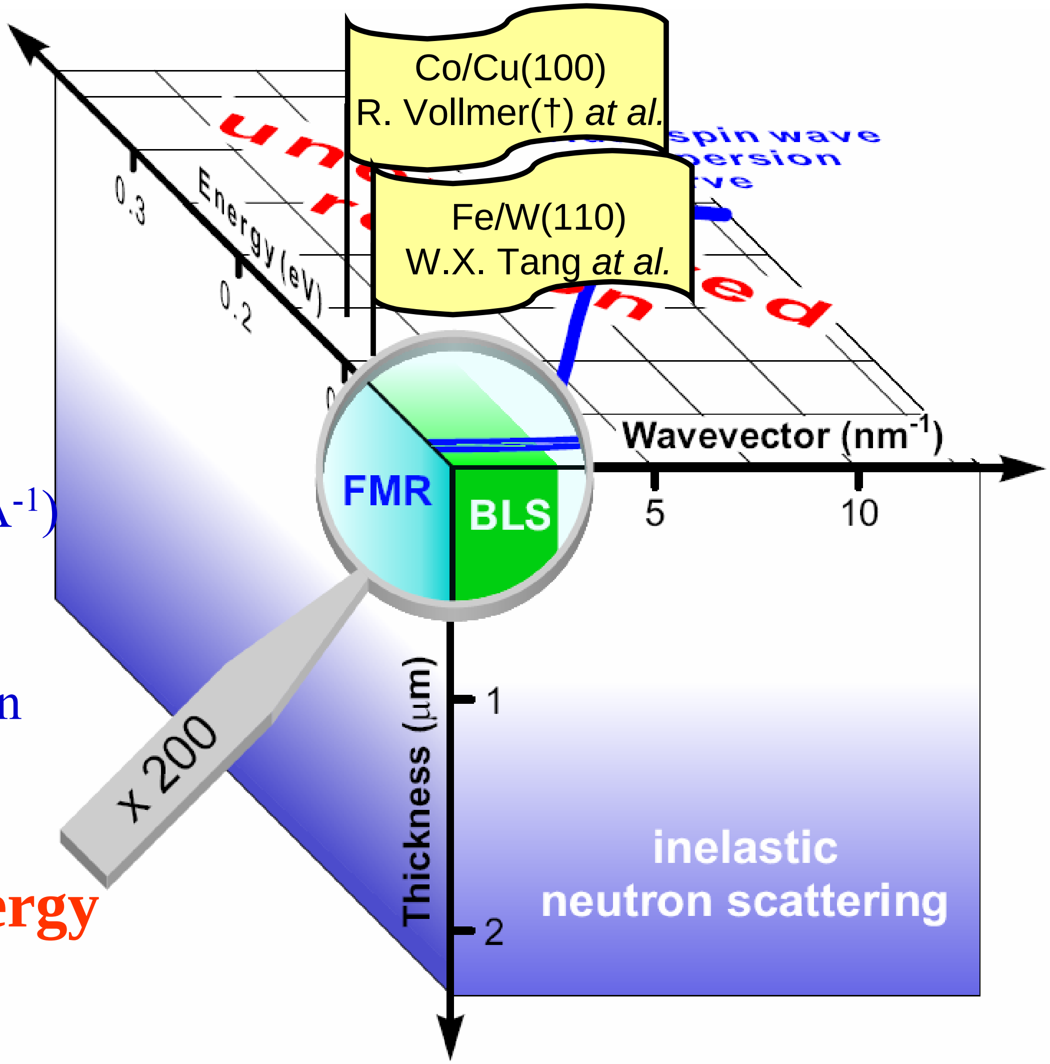
- Motivation
- Elemental magnetic excitations
- SPEELS
- Magnons in the Fe/W(110) films
- Summary

Motivation

- exchange coupling at surfaces
- magnetic moments at surfaces
- magnon / e-h pair coupling

Established methods:

- BLS small wave vector (10^{-2} Å^{-1})
- FMR wave vector close to 0
- INS low surface sensitive
- SP-STM no momentum resolution
- Our method: SPEELS



Spin-polarized electron energy loss spectroscopy

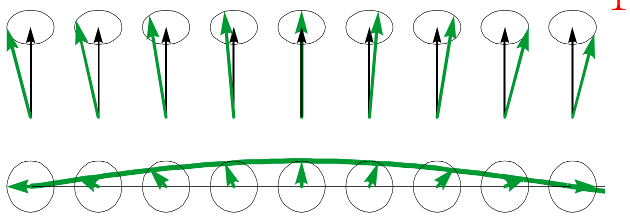
⇒ **Spin-dependent inelastic scattering of low energy electrons**

Magnetic excitations in itinerant electron ferromagnet

Spin waves

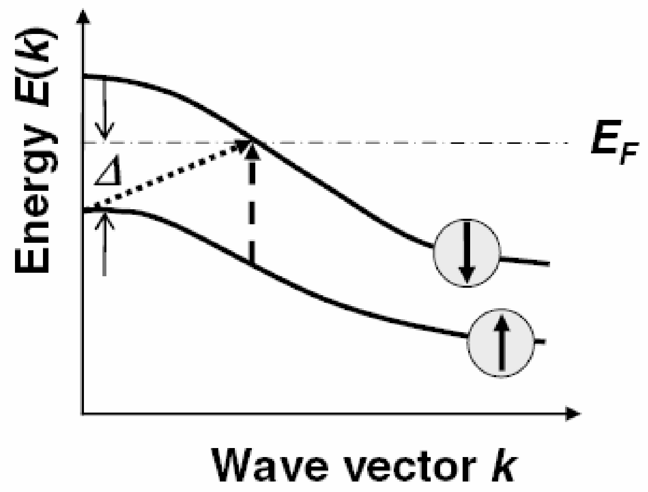
Spin waves - many - particle collective excitations

Magnons carry energy $\hbar\omega$, momentum k and spin $1\hbar$

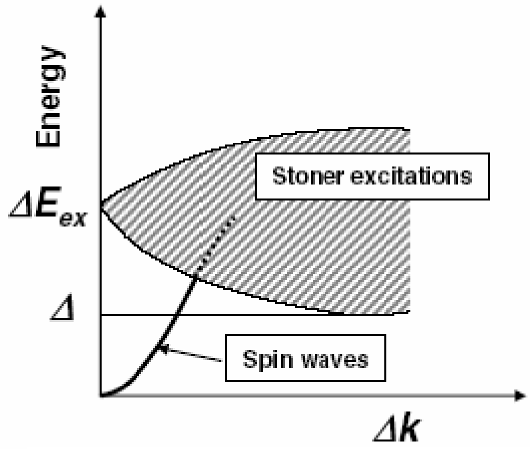


Stoner excitations similar to spin waves
but no long range correlation !!!
uncorrelated spin triplet electron-hole excitations

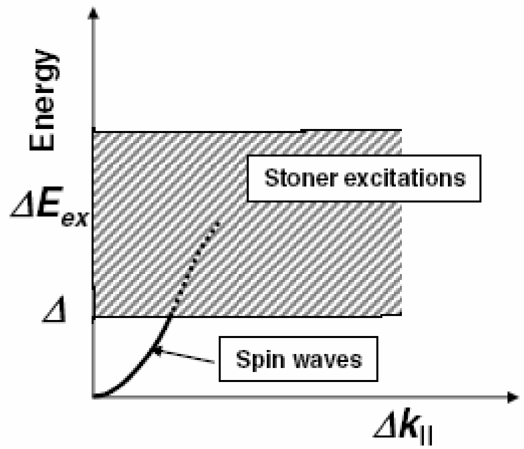
Stoner excitations



Bulk crystals: full k-conservation



Surfaces, thin films: only $k_{||}$ is conserved

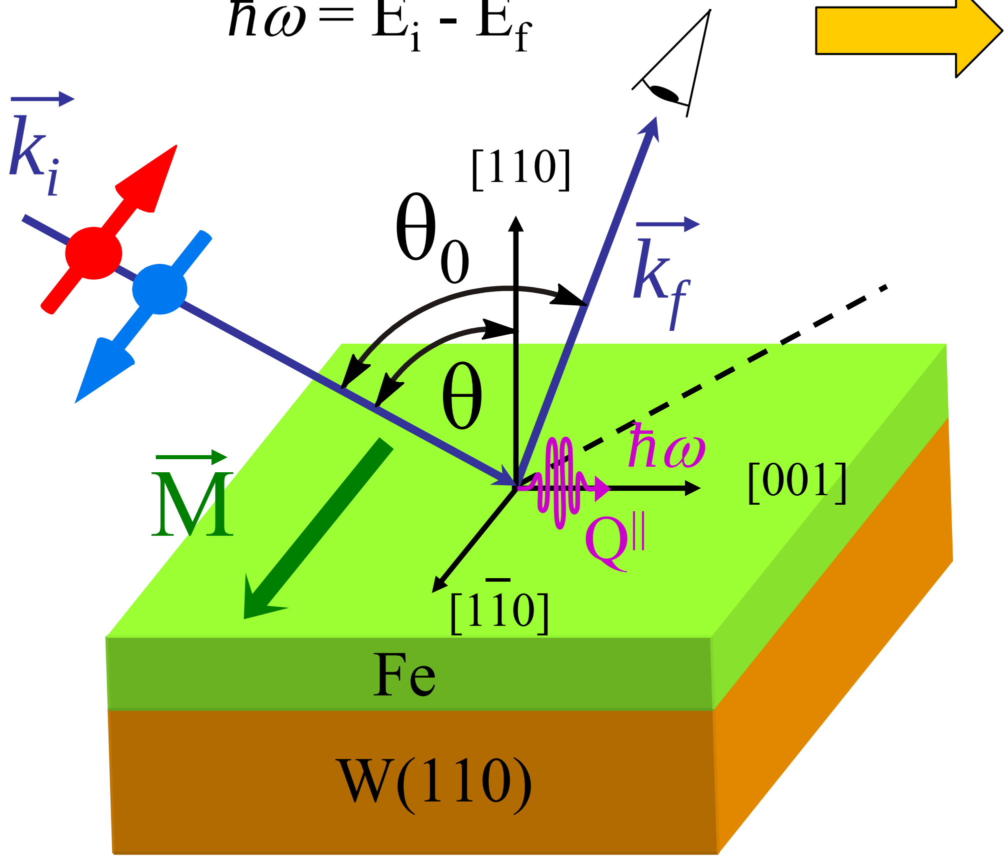


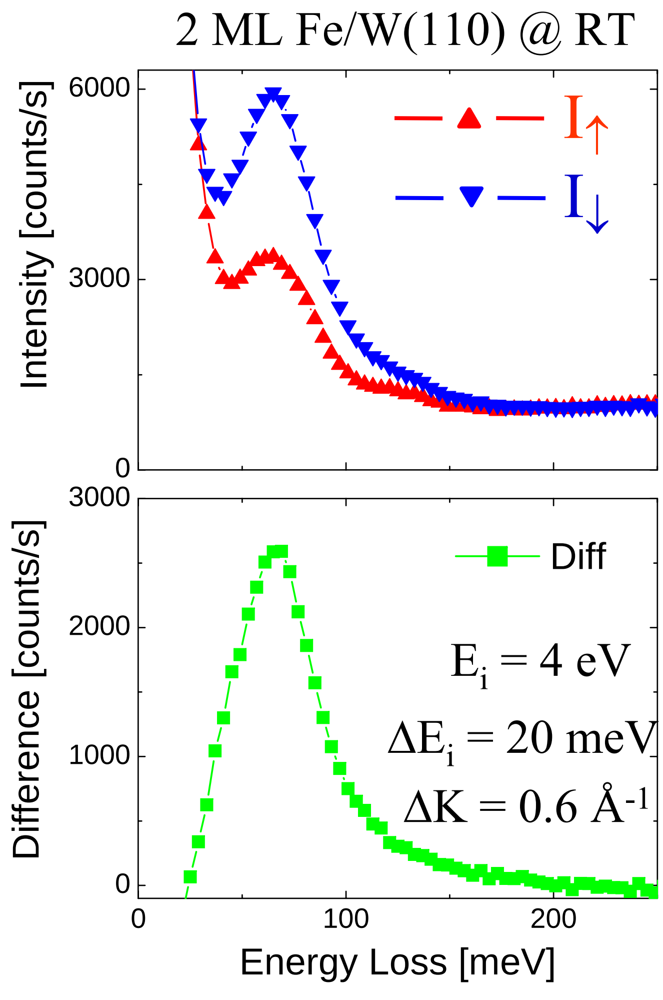
The high wave vector spin waves in itinerant systems are strongly damped

Inelastic electron scattering – SPEELS

$$-Q^{\parallel} = \Delta K^{\parallel} = k^{\parallel}_f \sin(\theta_0 - \theta) - k^{\parallel}_i \sin(\theta)$$

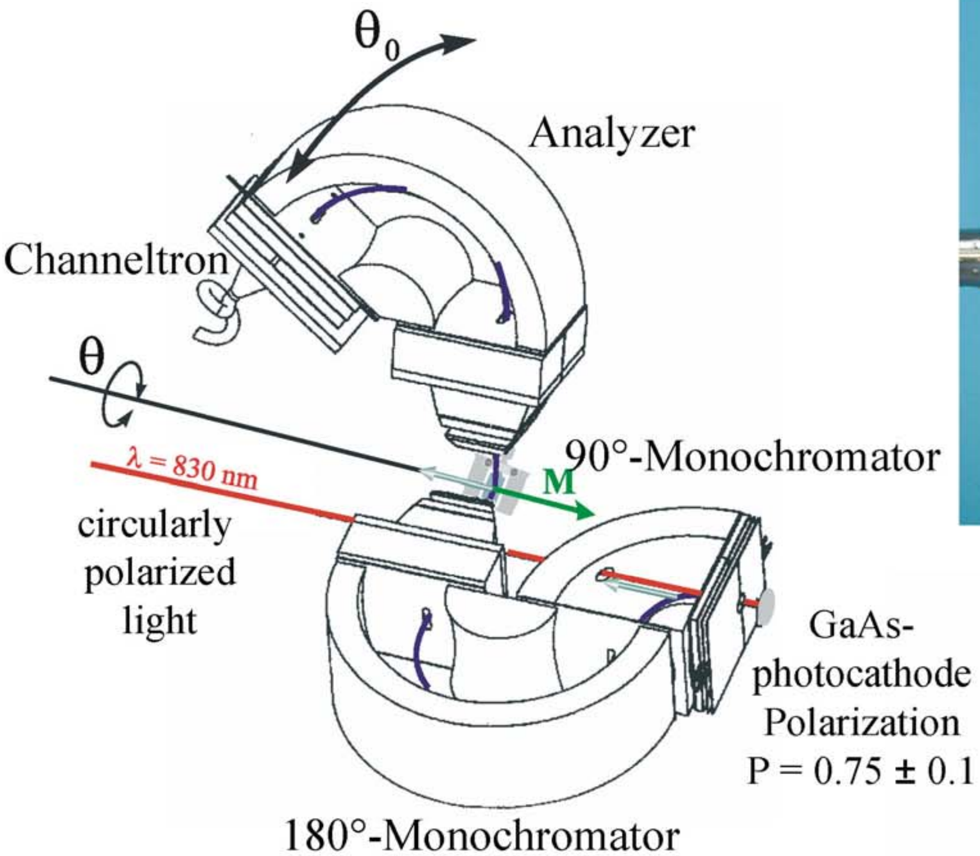
$$\hbar\omega = E_i - E_f$$

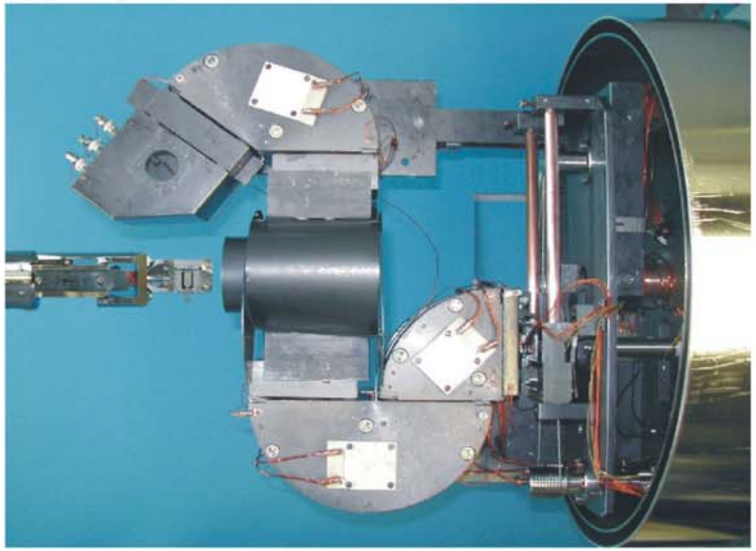


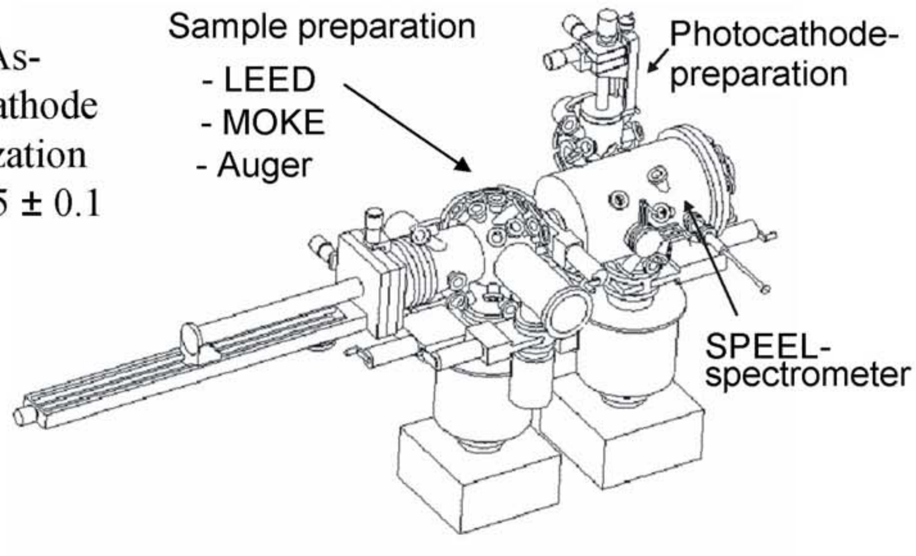


Difference $\Delta I = I_\downarrow - I_\uparrow$

The SPEEL – Spectrometer



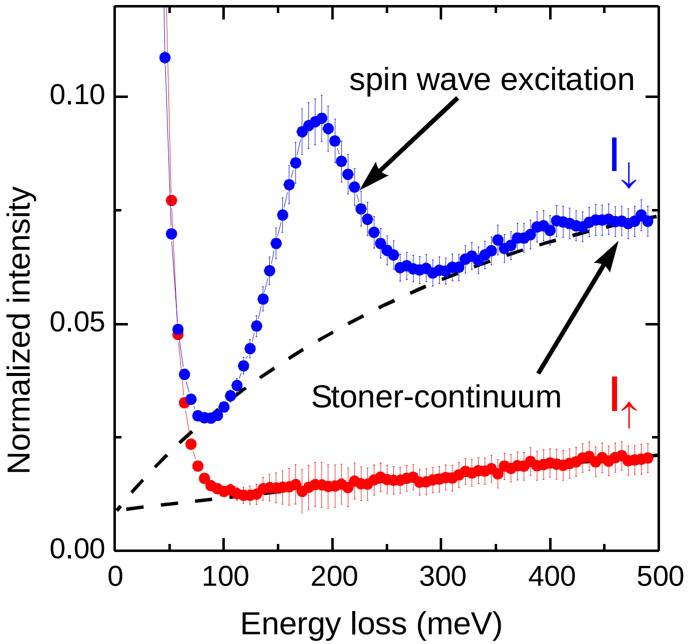




H. Ibach, D. Bruchmann, R. Vollmer, M. Etzkorn, P. S. Anil Kumar and J. Kirschner, Rev. Sci. Instrum., 74 (2003) 4089.

SPEELS – fundamental example

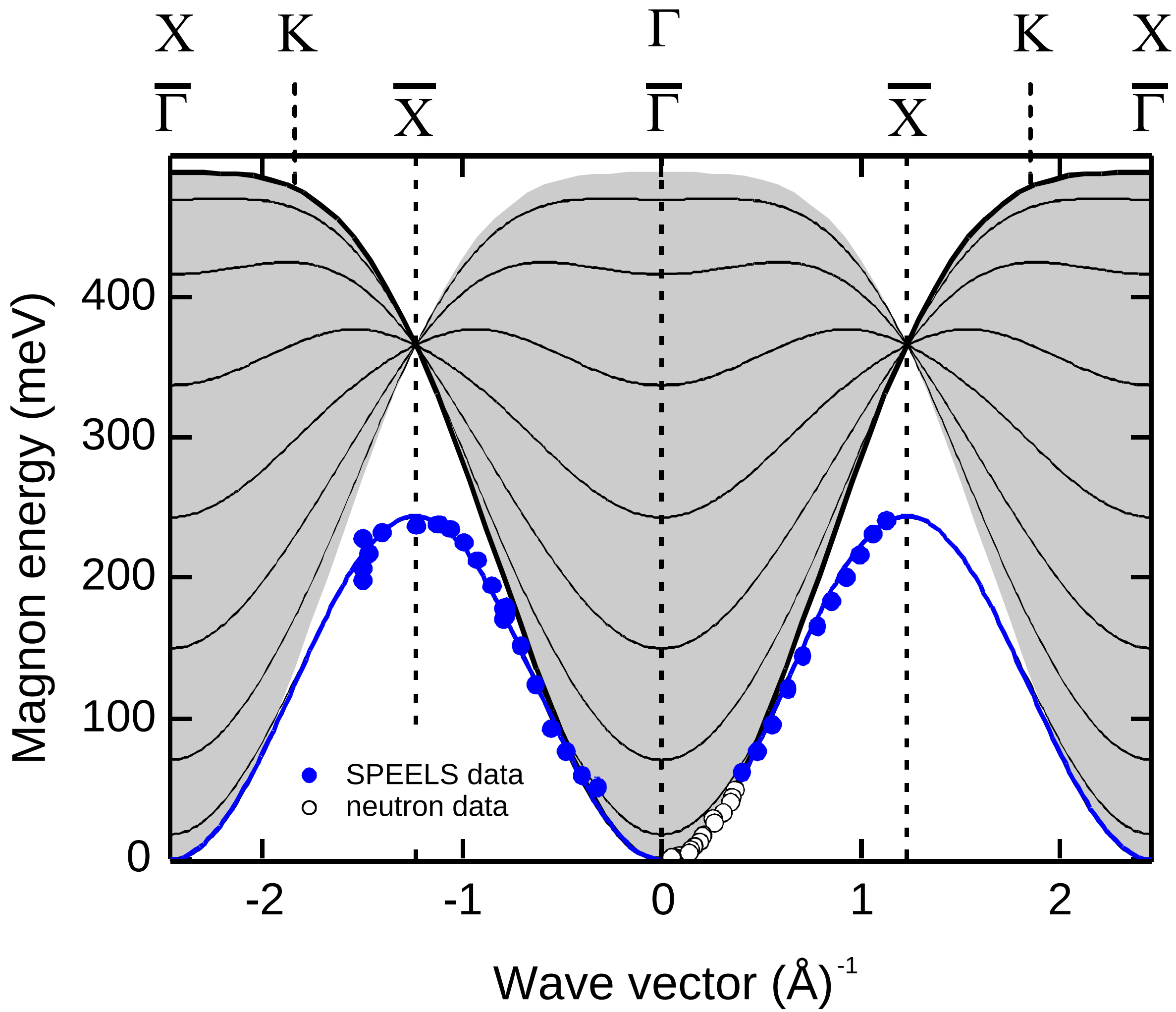
8 ML Co on Cu(001)



$E_i = 6.7$ eV

$\Delta E_i = 40$ meV

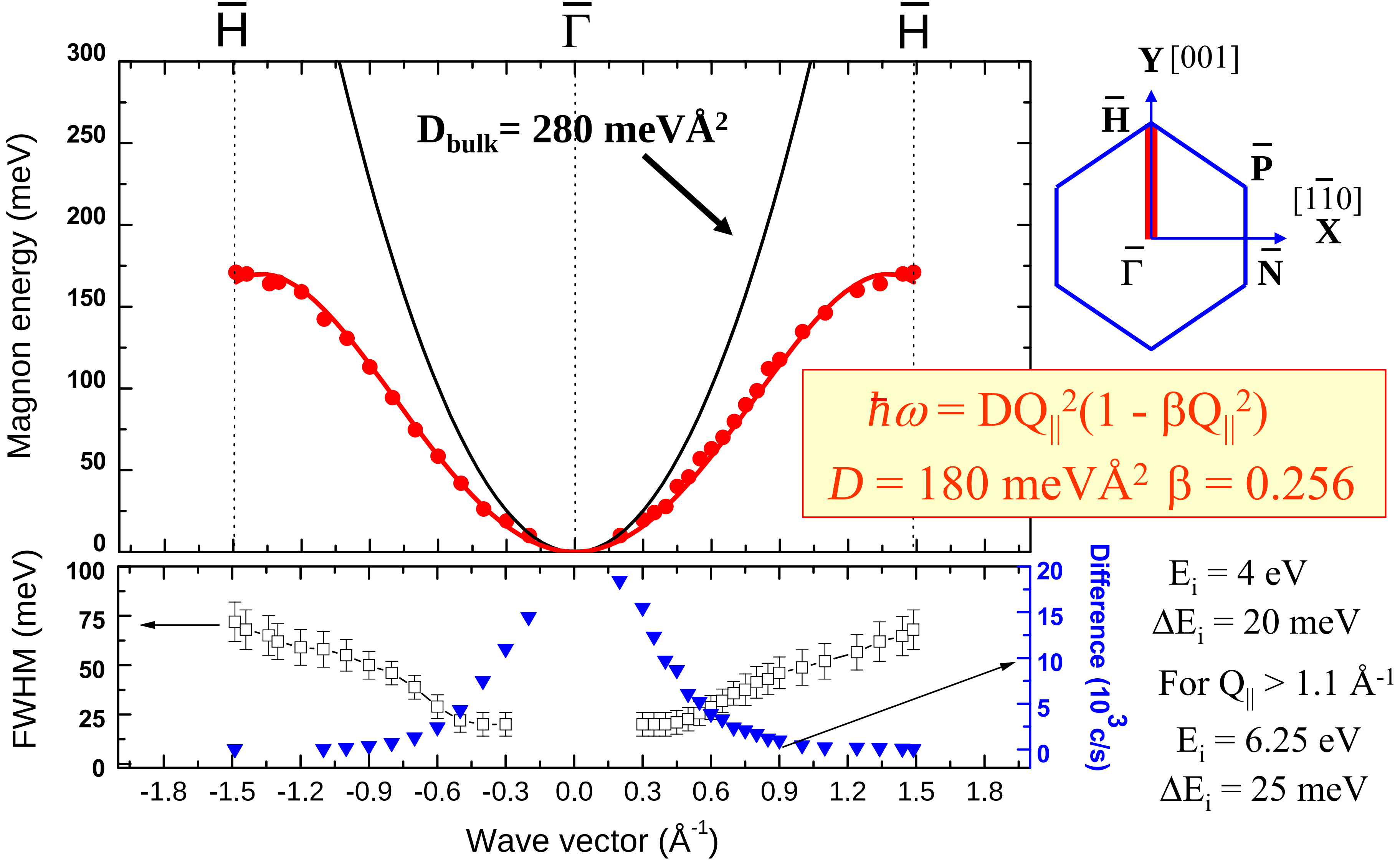
$\Delta K = 0.87$ Å^{-1}



R. Vollmer (†), M. Etzkorn, P. S. Anil Kumar, H. Ibach, J. Kirschner, Phys. Rev. Lett. **91**, 147201 (2003).

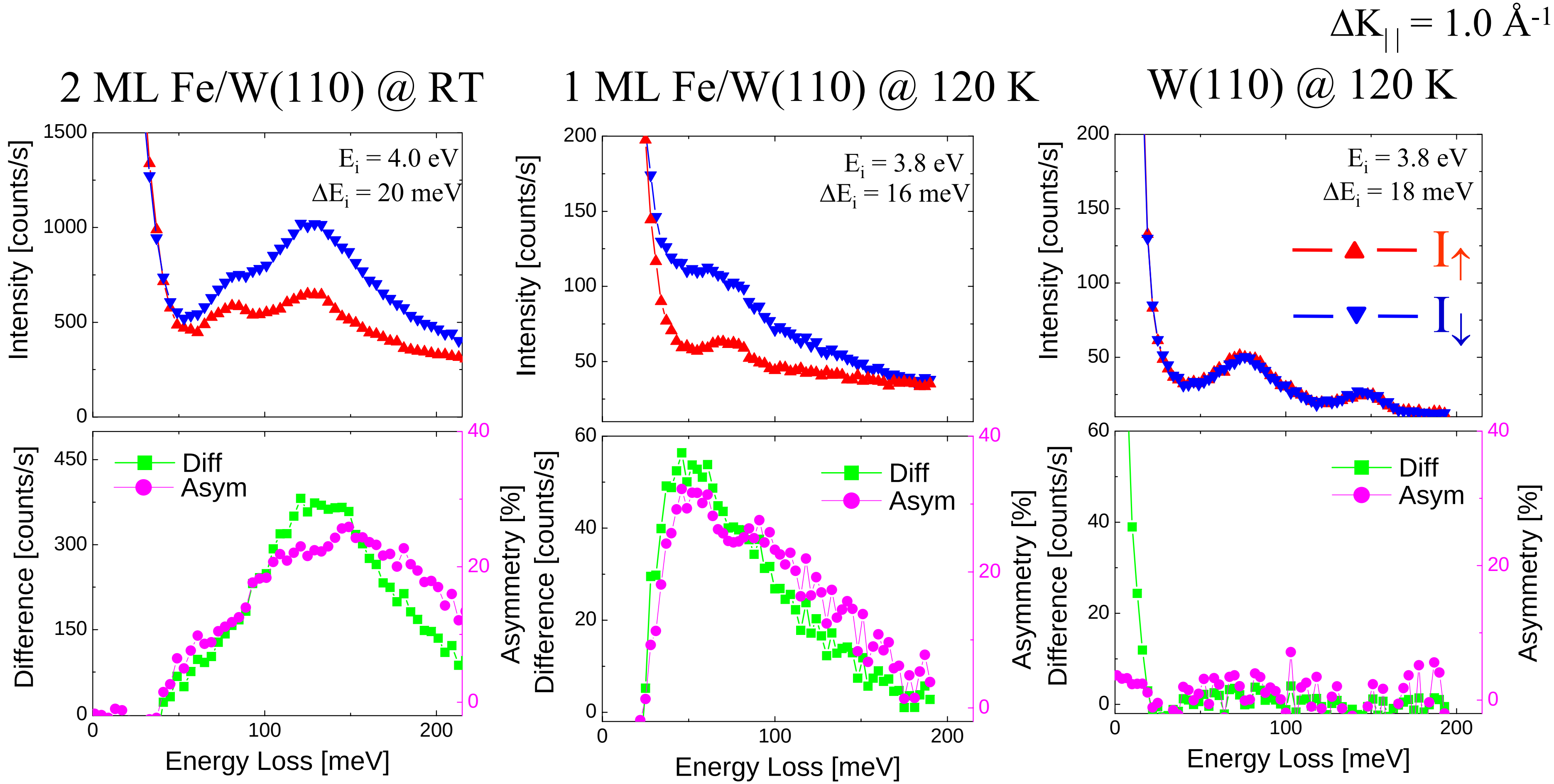
neutron data: R. N. Sinclair and B. N. Brockhouse, Phys. Rev. **120**, 1638 (1960).

Magnon dispersion for the 2 ML Fe/W(110) film



W. X. Tang, Y. Zhang, I. Tudosa, J. Prokop, M. Etzkorn, J. Kirschner, Phys. Rev. Lett. **99**, 087202 (2007).

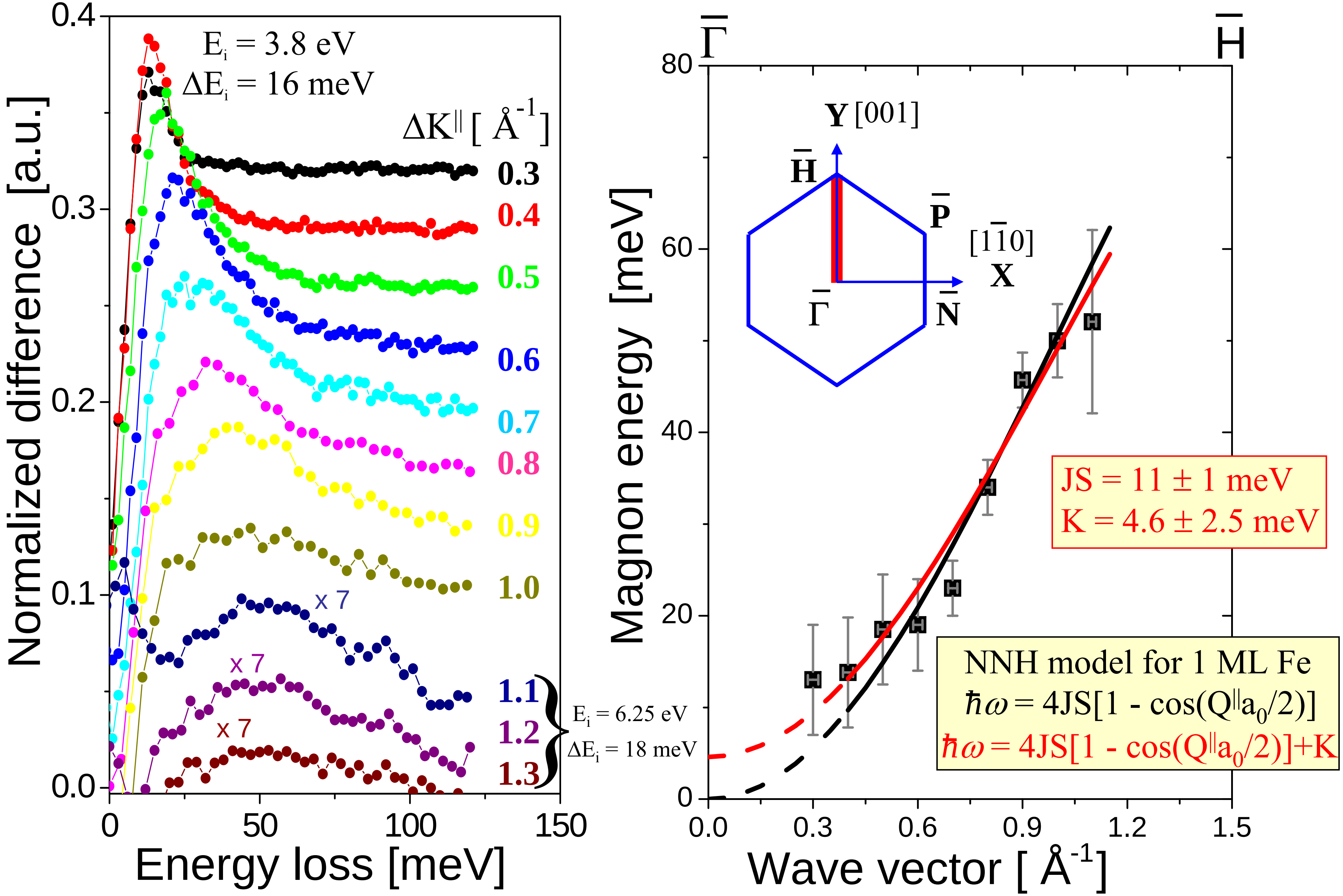
The SPEELS structures for 1 ML Fe/W(110)



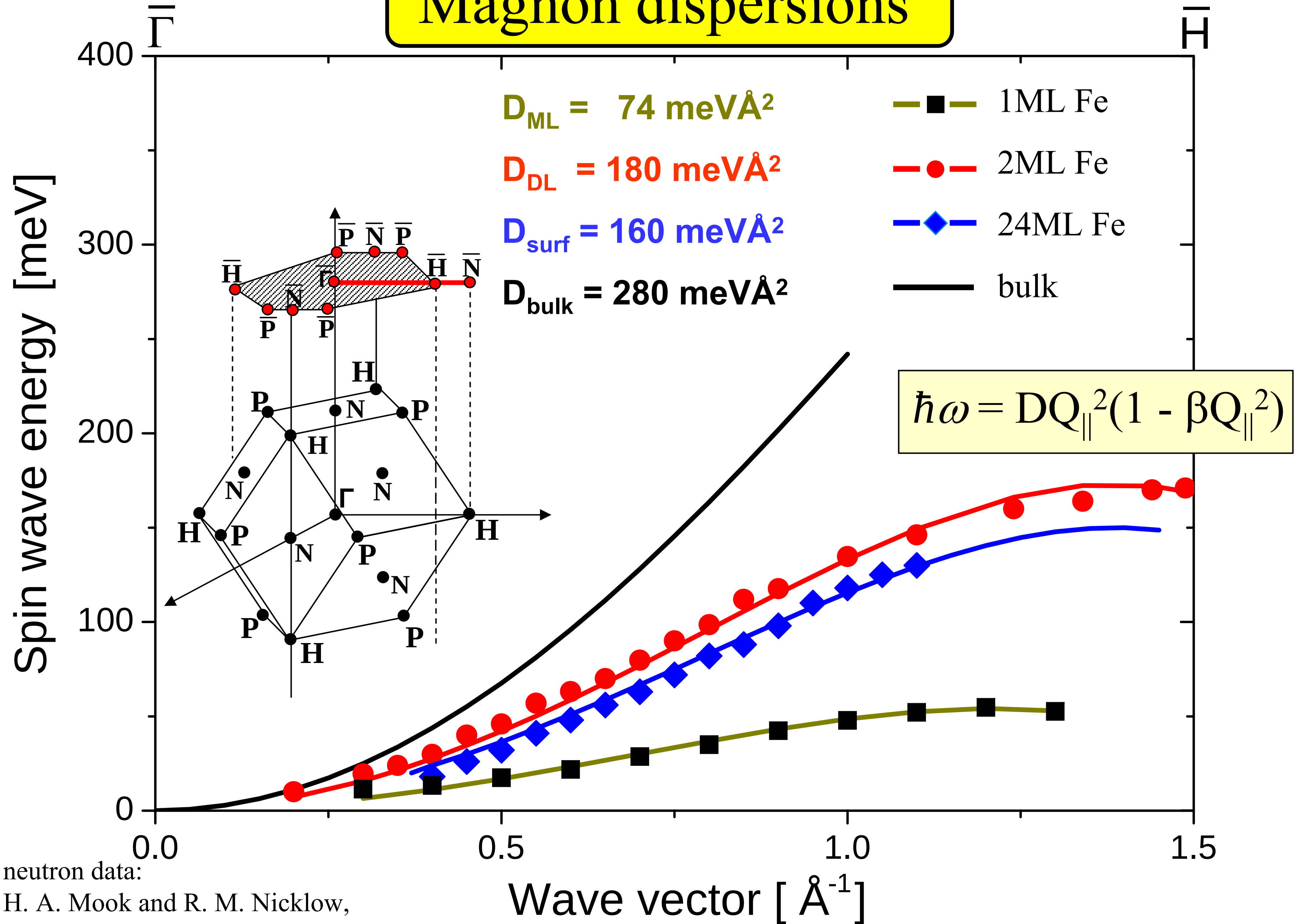
Difference $\Delta I = I_\downarrow - I_\uparrow$

Asymmetry $\Delta I = \dfrac{I_\downarrow - I_\uparrow}{I_\downarrow + I_\uparrow}$

Magnon dispersion for 1ML Fe/W(110)



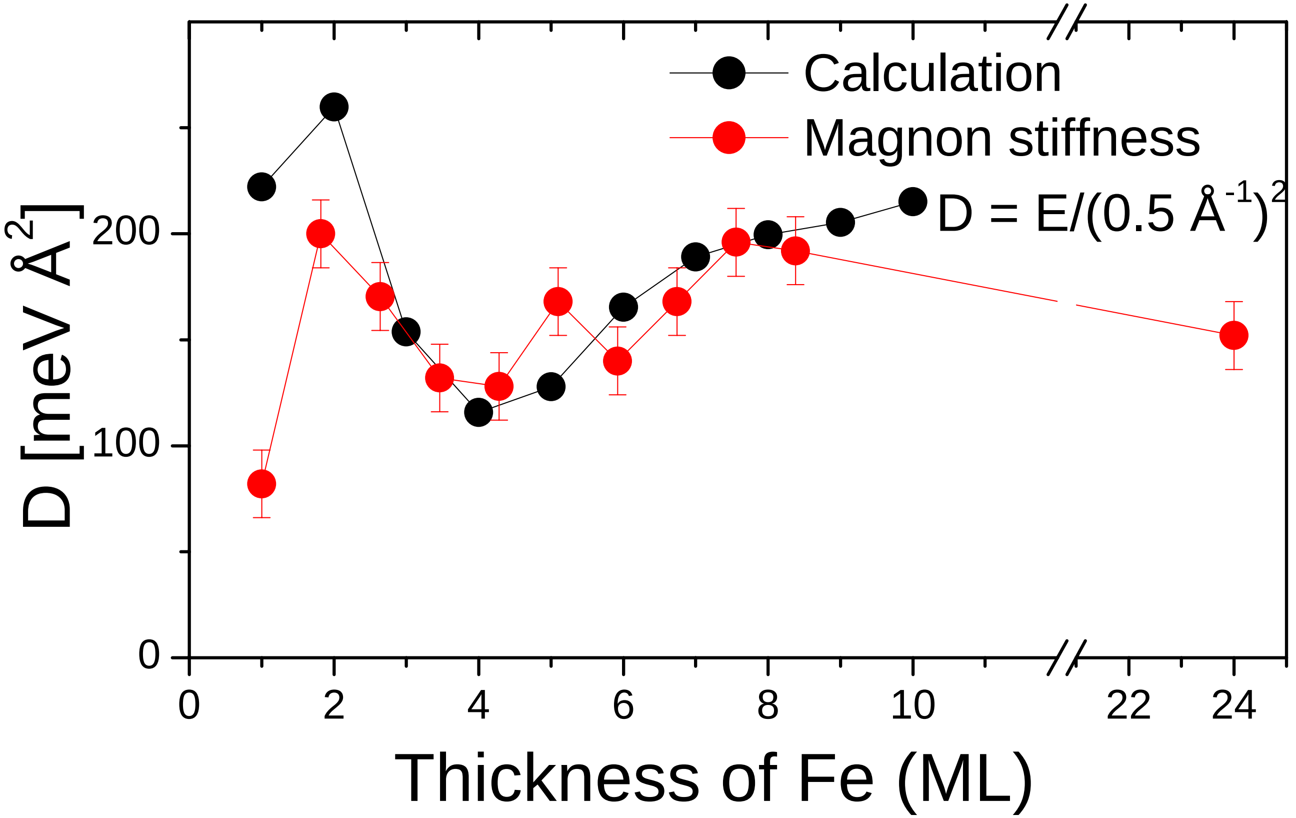
Magnon dispersions



neutron data:
H. A. Mook and R. M. Nicklow,
Phys. Rev. B 7, 336 (1973).

Magnon stiffness D – the thickness dependence

R. B. Muniz, A.T. Costa, and D.L. Mills,
J. Phys.: Condens. Matter **15**, S495 (2003).



Magnon stiffness D changes non-monotonously with the Fe film thickness

Summary

- The pronounced magnon peaks are observed in the 2 ML Fe/W(110) at RT. The magnon dispersion for the Fe films is measured up to the SBZ for the first time. A stiffness coefficient for the 2 ML Fe/W(110) is clearly different from that in the bulk Fe.

- The magnons in the 1 ML Fe/W(110) are much softer than that in the bulk Fe, softer than those in the 2 ML Fe/W(110) film, and in the Fe(110) surface.

- For the thicker Fe films, the high wave vector magnons are observed as well. The magnon stiffness coefficient D changes non-monotonously with the Fe film thickness.

Authors

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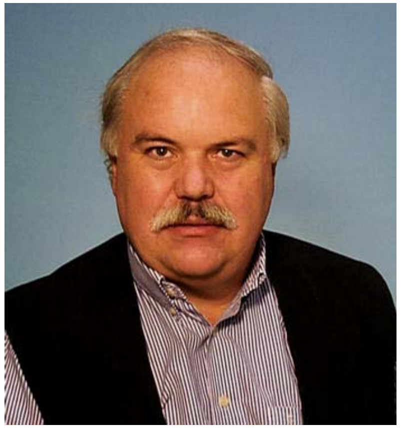

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