Using MACS to probe spinon in 1-D S =1/2 antiferromagnetic chain

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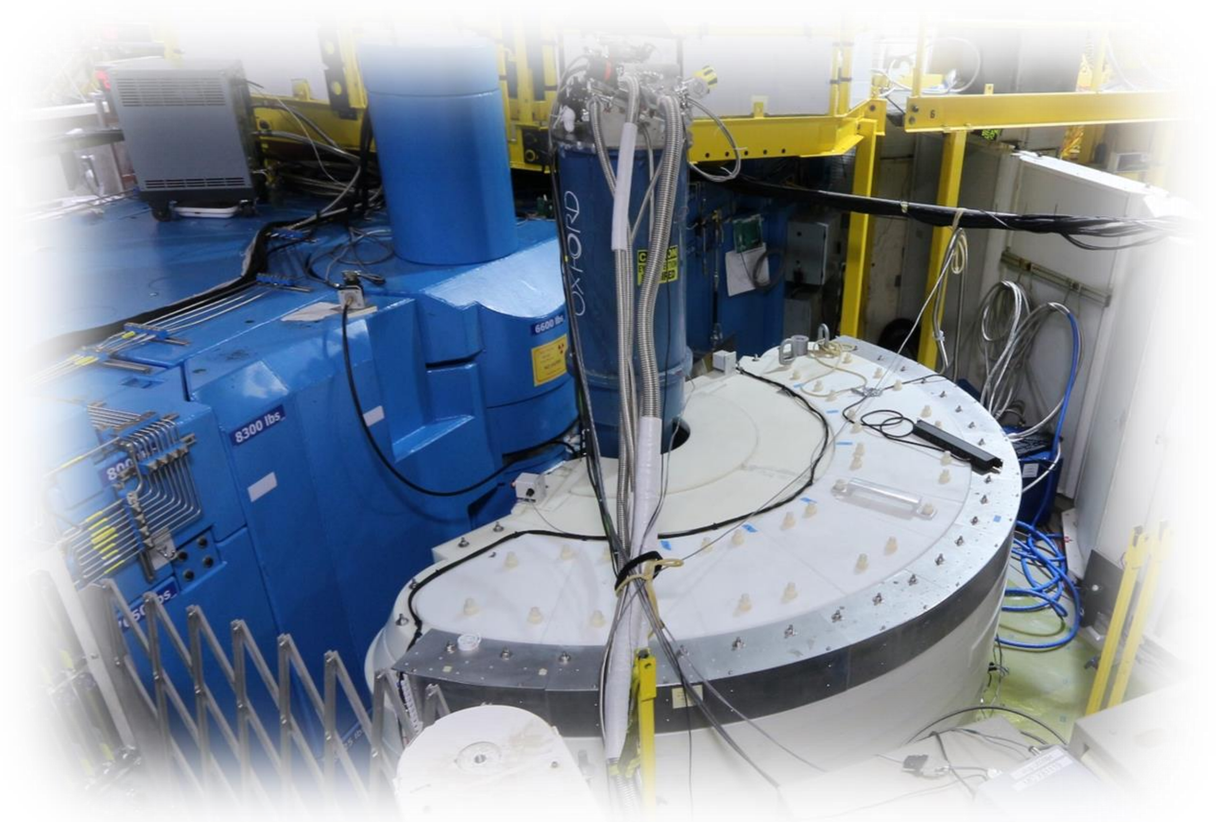
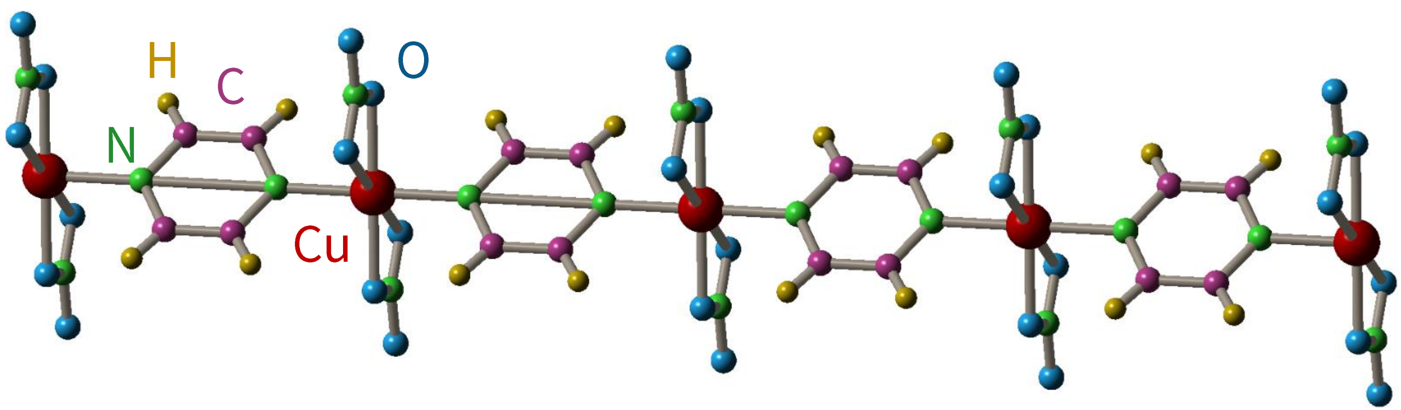


Many questions:

- What is a one-dimensional antiferromagnet?
- What is a spinon?
- Why do we need neutron scattering?
- Why do we use MACS?

One dimensional material

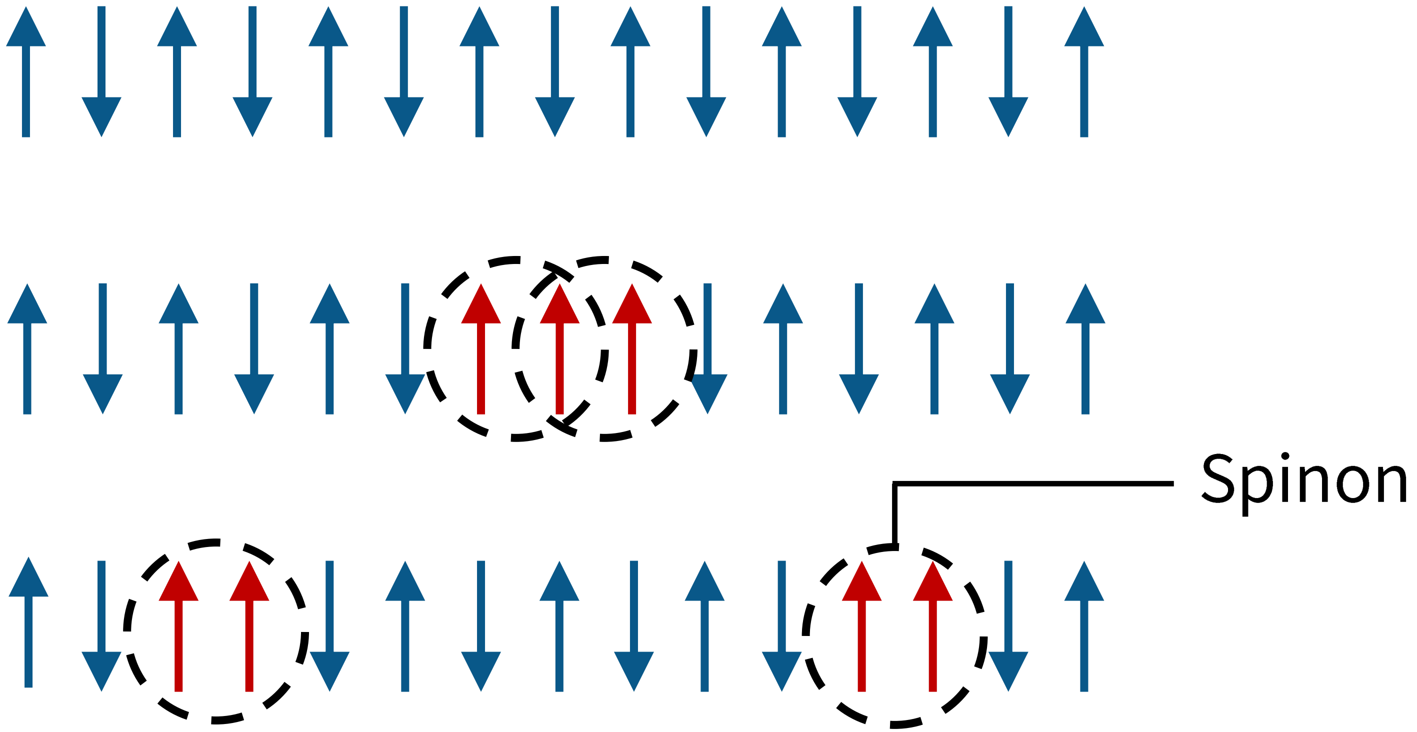
CuPzN: $Cu(C_4H_4N_2)(NO_3)_2$, Cu has spin S = 1/2



$\uparrow \quad \downarrow \quad \uparrow \quad \downarrow \quad \uparrow$

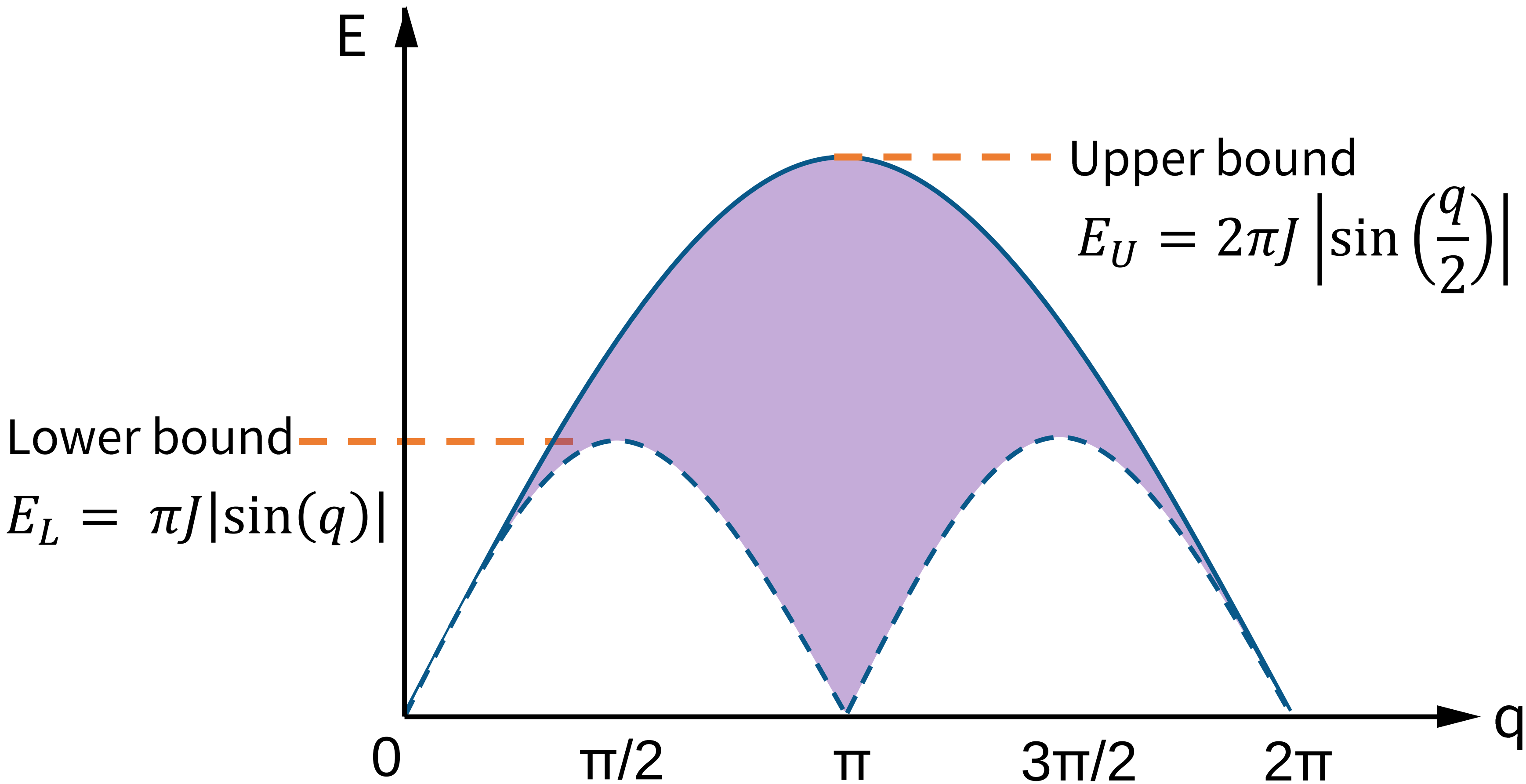
Antiferromagnetic
coupling

What is the spinon?



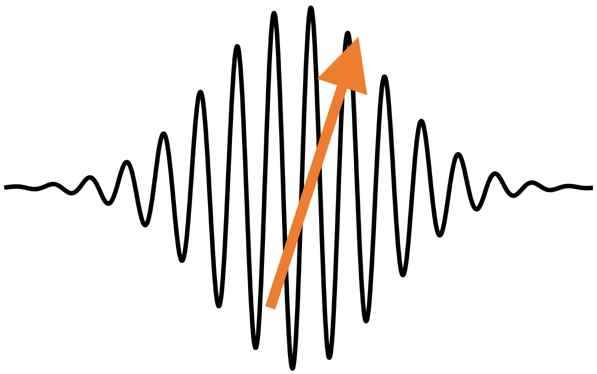
Hamiltonian of 1-D Heisenberg model:

$$\hat{H} = 2J \sum_{r} \vec{S}_r \cdot \vec{S}_{r+1}$$



How to detect spin excitations?

Neutron:



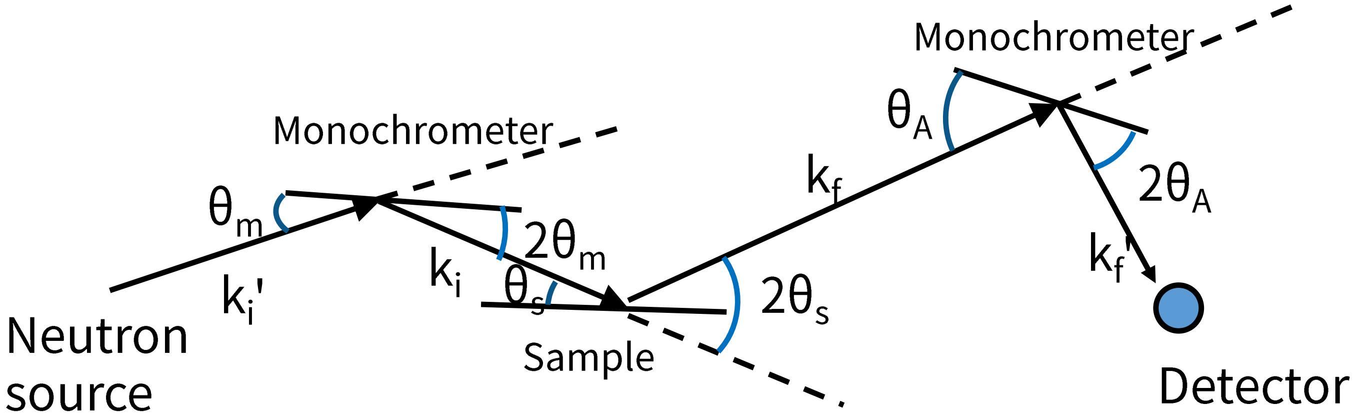
1. $E = \dfrac{\hbar^2 k^2}{2m}$

2. $\vec{\mu} \propto \vec{S}(= 1/2)$

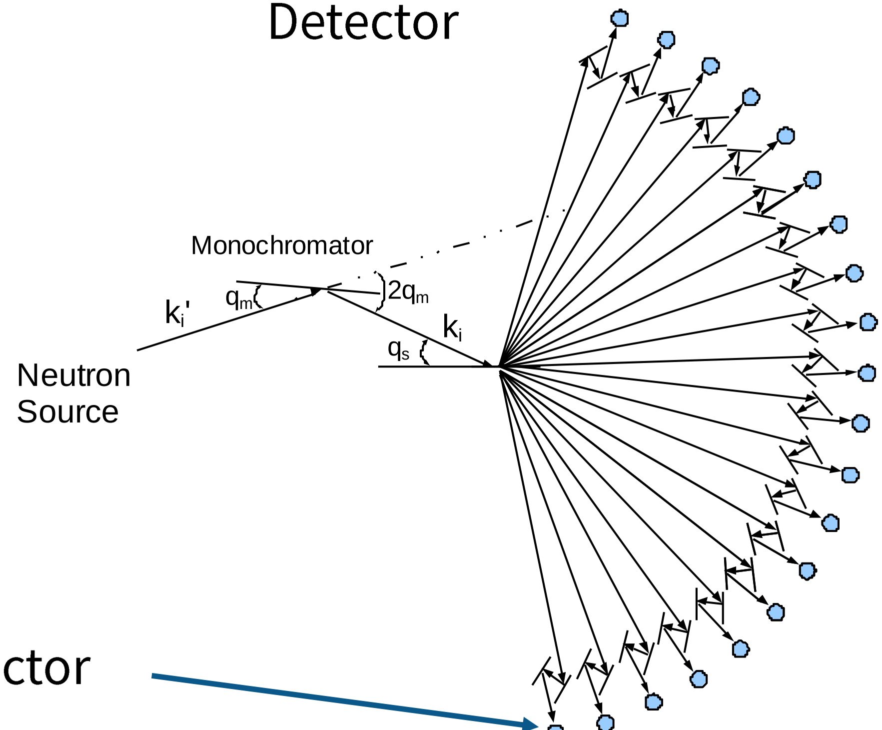
$\Downarrow$

Fourier transform of correlation function in space time S(q,w)

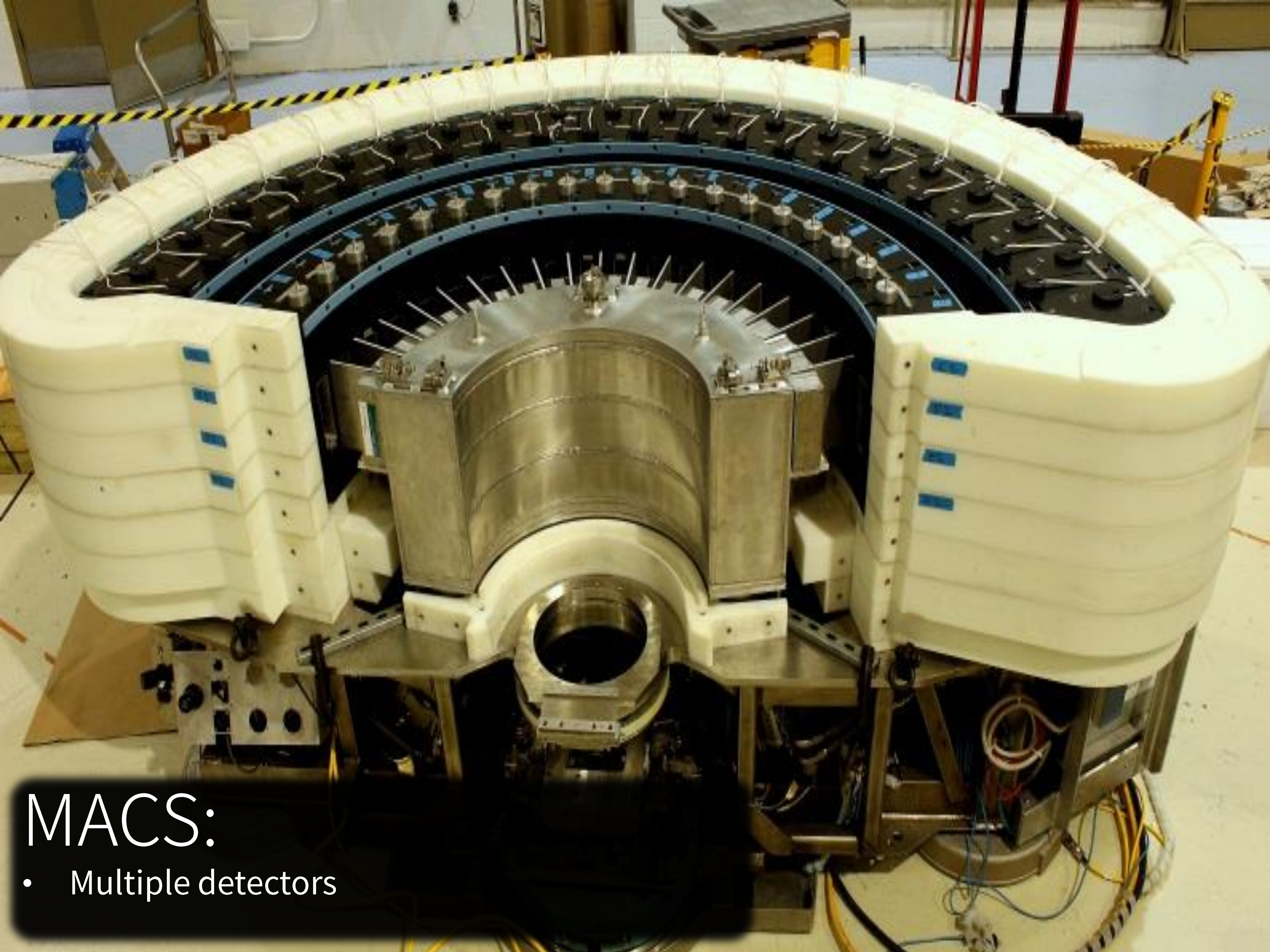
Triple axis neutron scattering



$$S(q, E)$$
$$q = k_i - k_f$$
$$E = E_i - E_f$$



MACS Detector

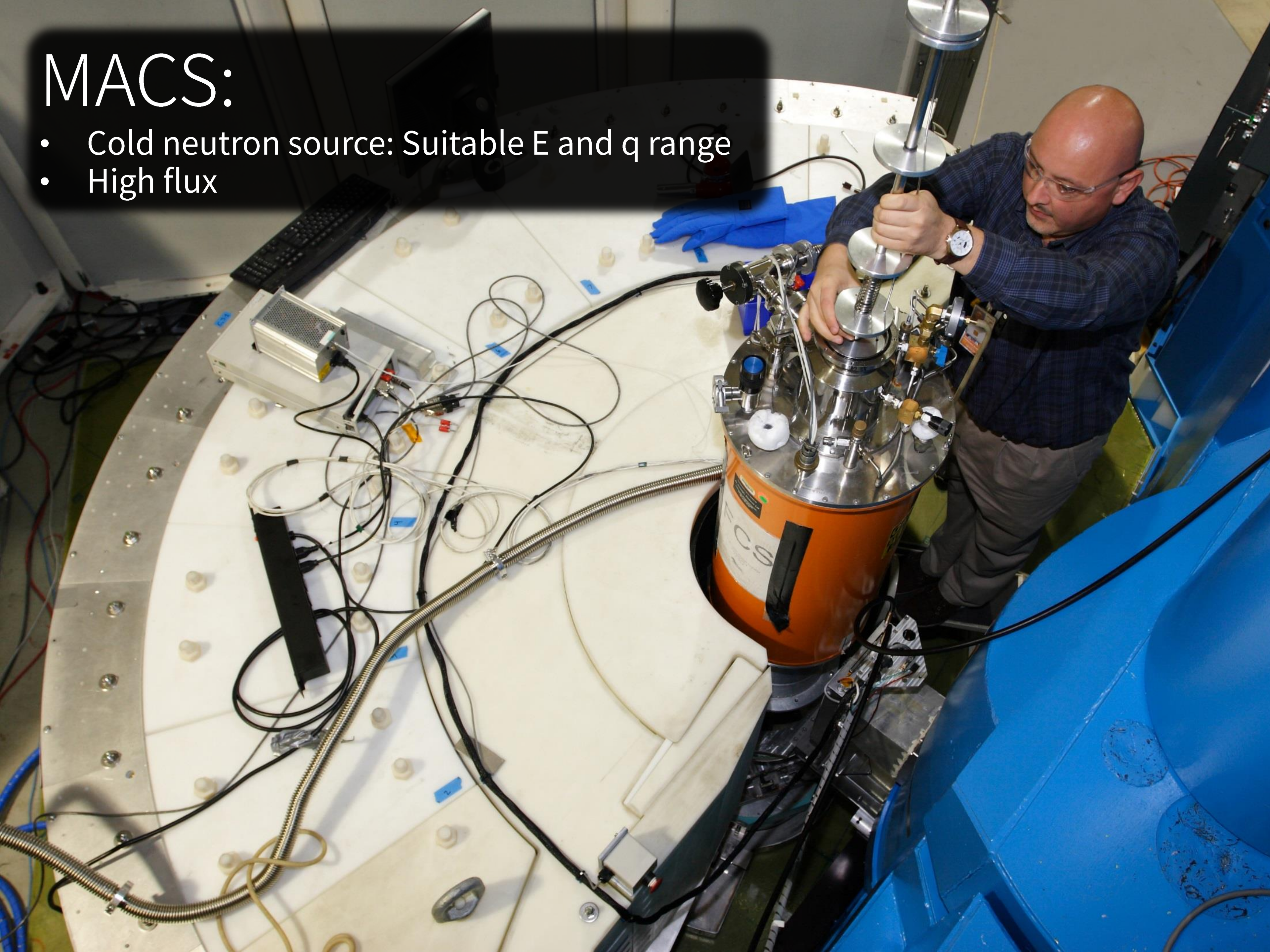


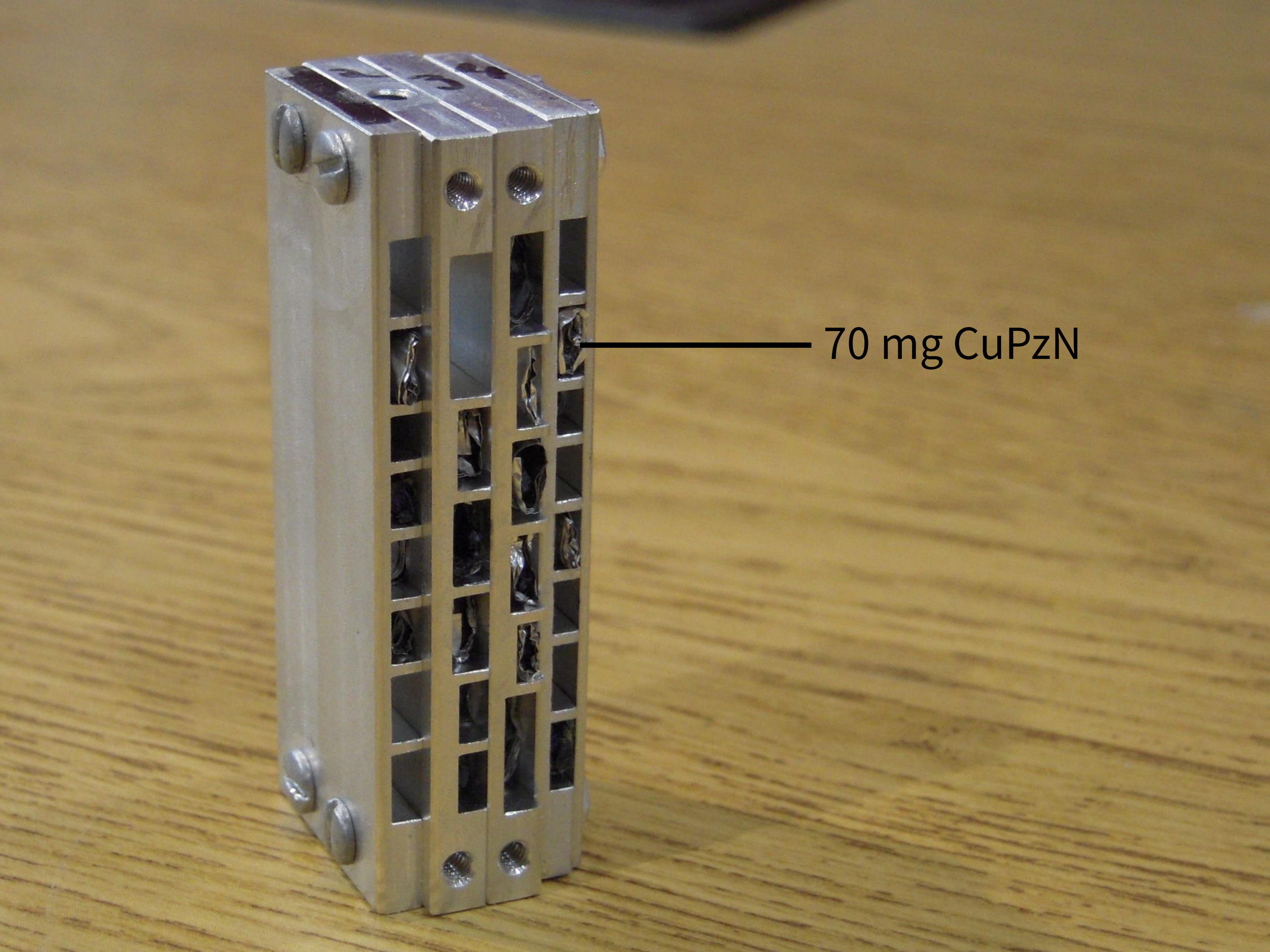
MACS:

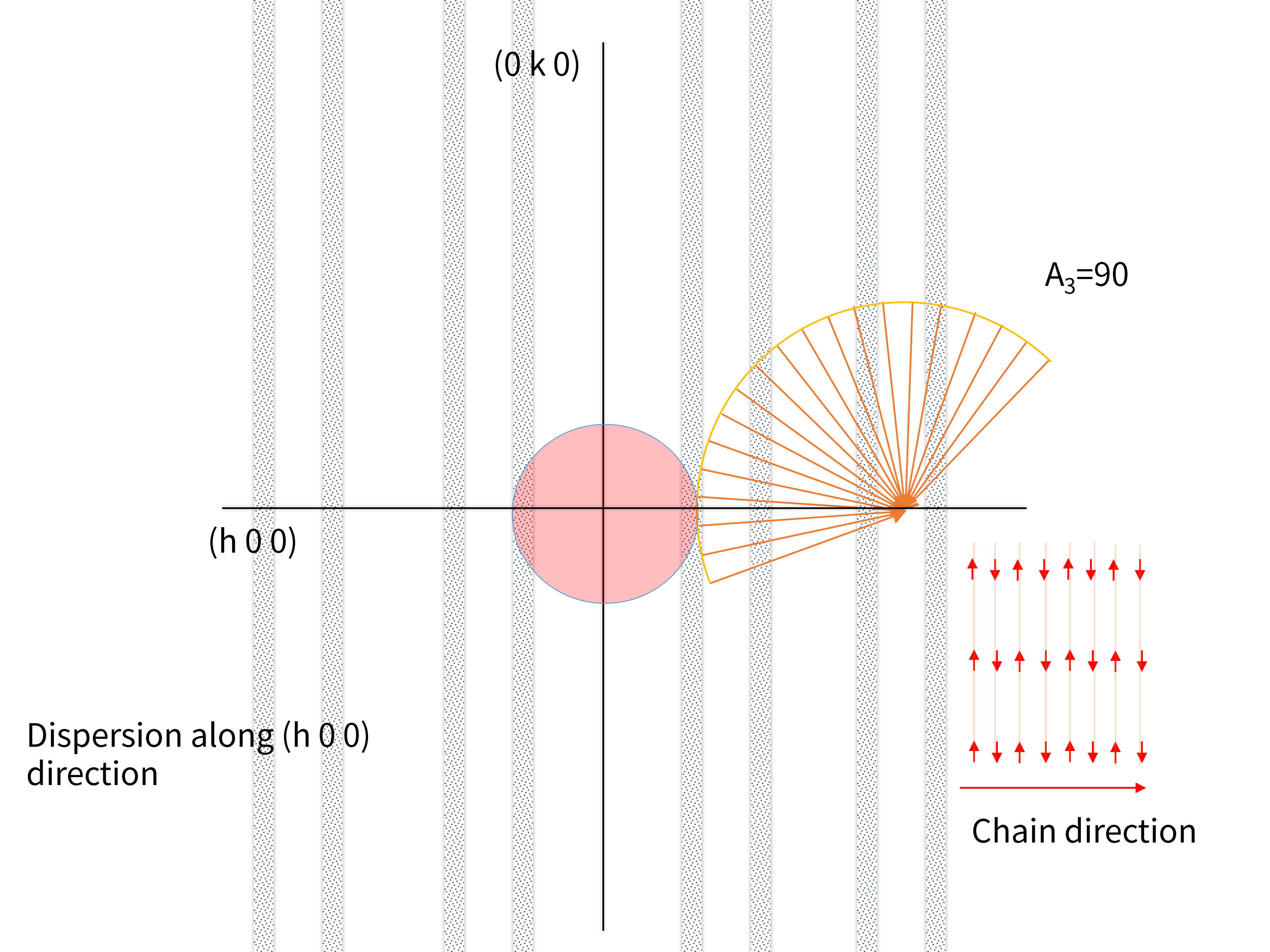
- Multiple detectors

MACS:

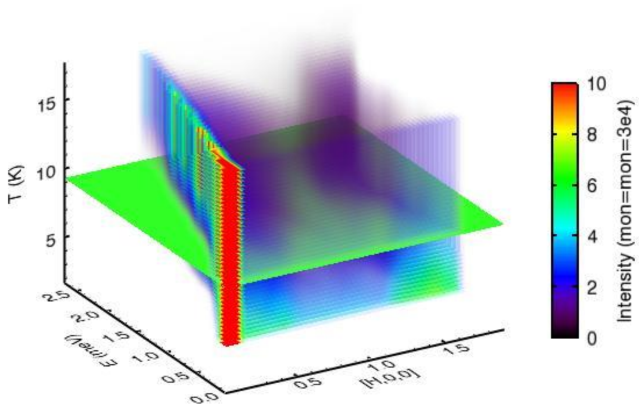
- Cold neutron source: Suitable E and q range
- High flux

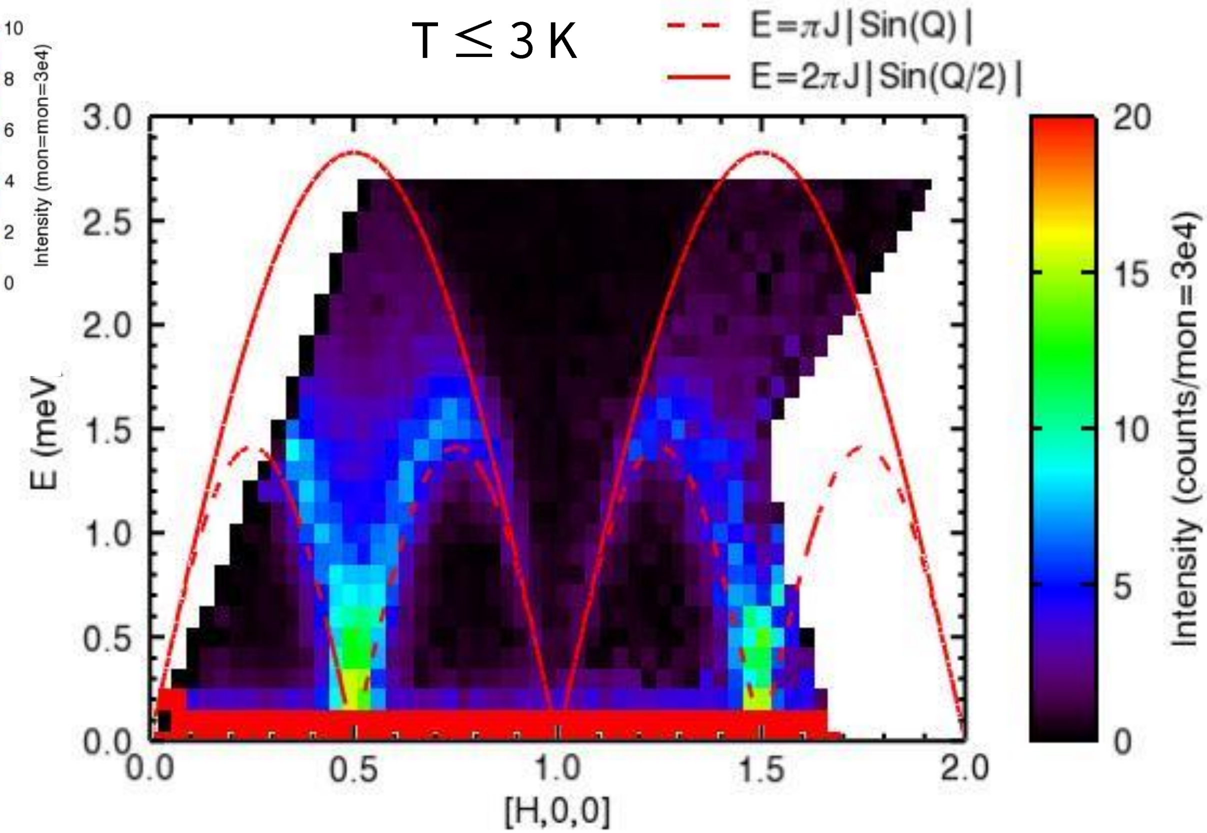



70 mg CuPzN


(0 k 0)
A_3=90
(h 0 0)
Dispersion along (h 0 0) direction
Chain direction

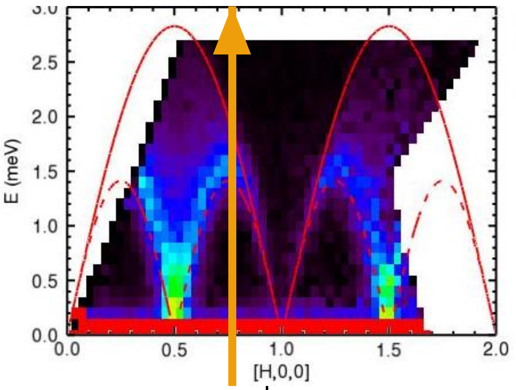
(E, q) map:



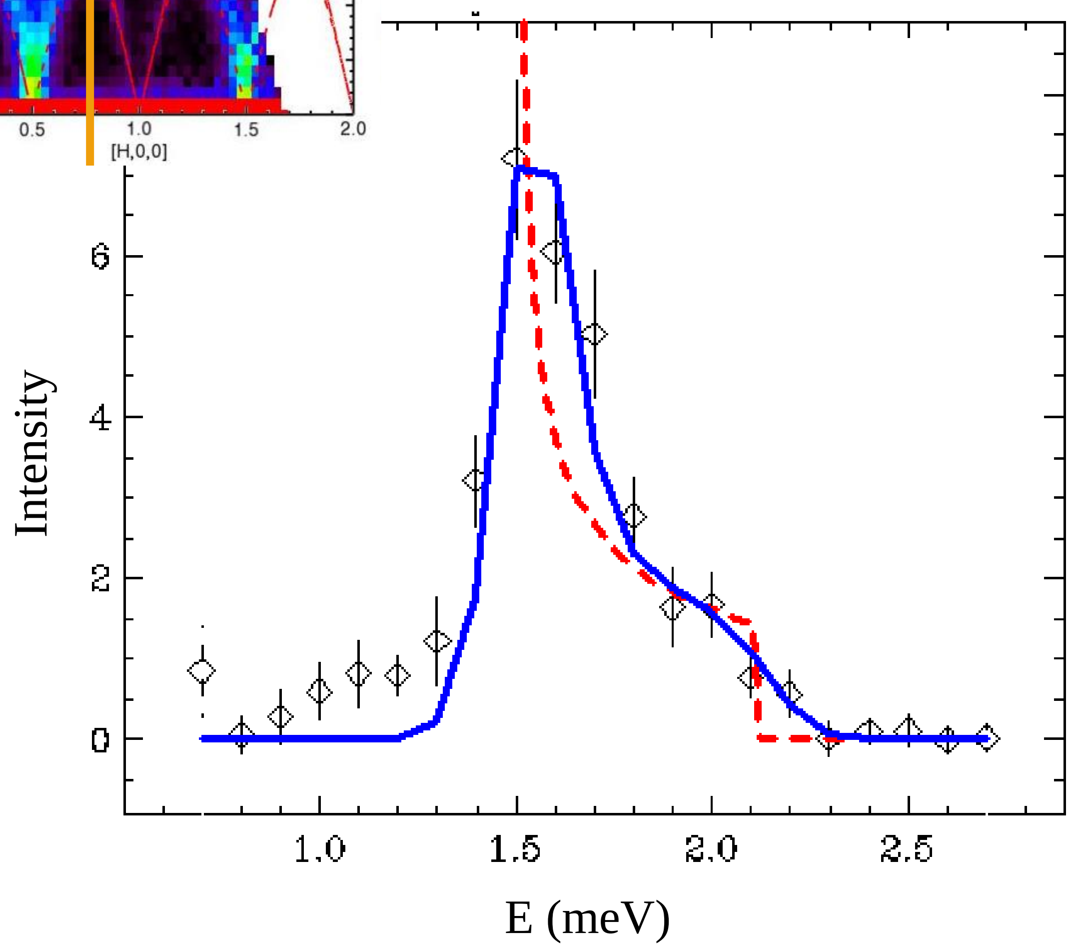


Energy dispersion is consistent with theoretical prediction.

E cut at H = 0.75



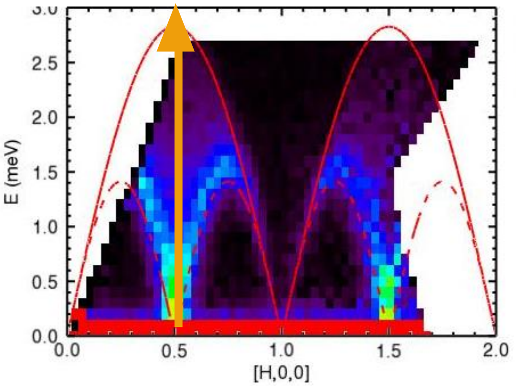
$$S(q,E) = \frac{A_M \Theta\,(E - E_l\,(q))\Theta(E_u(q) - E)}{\sqrt{E^2 - E_l^2\,(q)}}$$

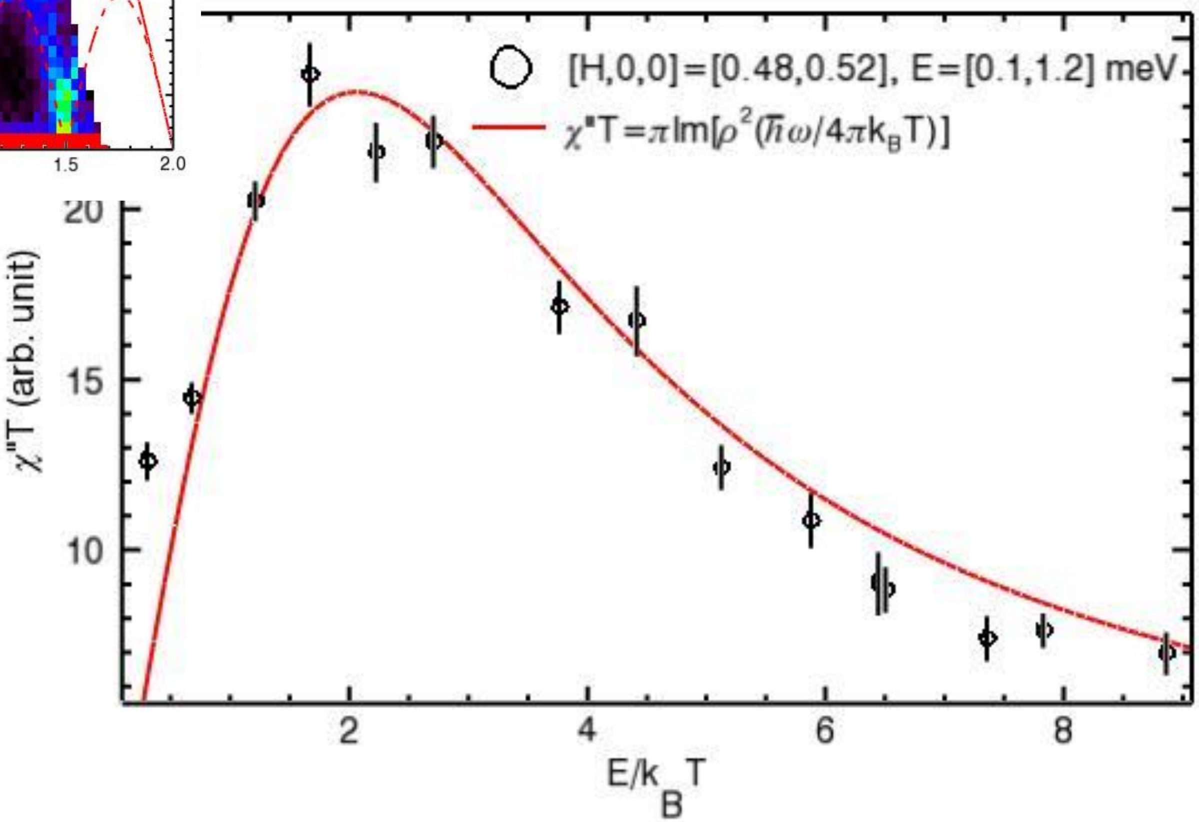


Fitting result:

J = 0.476 meV

E cut at H = 0.5





The susceptibility scales with E/T.

Take home message

> “Flux, (q,E) range/resolution available at MACS provide an ideal environment in which spin fluctuations in a low dimensional quantum system may be probed.”

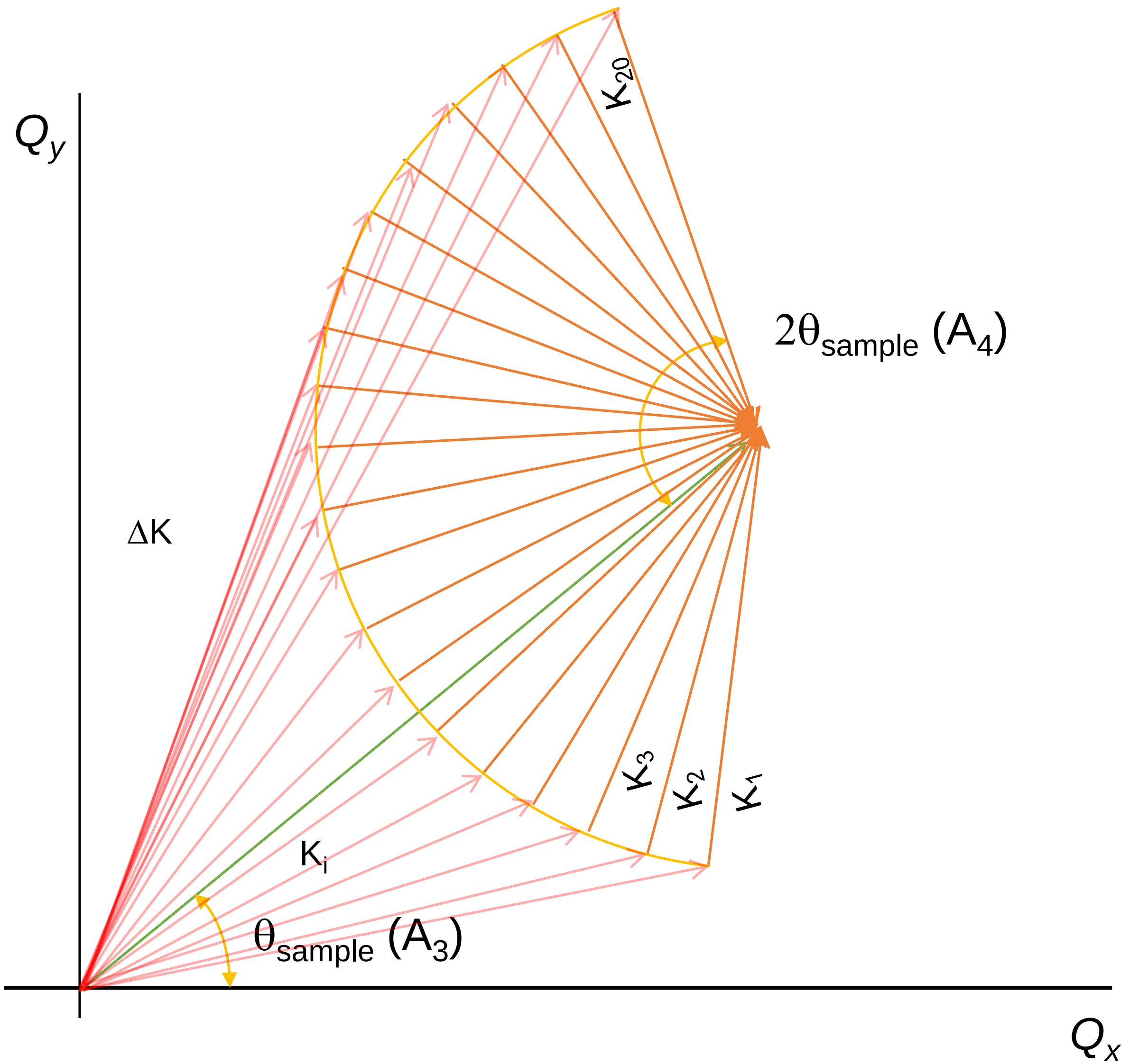
CHRNS
Center for High Resolution Neutron Scattering
NSF NIST

Thank you for your attention.

Thanks to Yamali, Yun, and all the NCNR staff.

$$\chi'' T = A\,\mathrm{Im}[\frac{E}{4\pi k_B T}]$$

Why the donut shape in reciprocal space?



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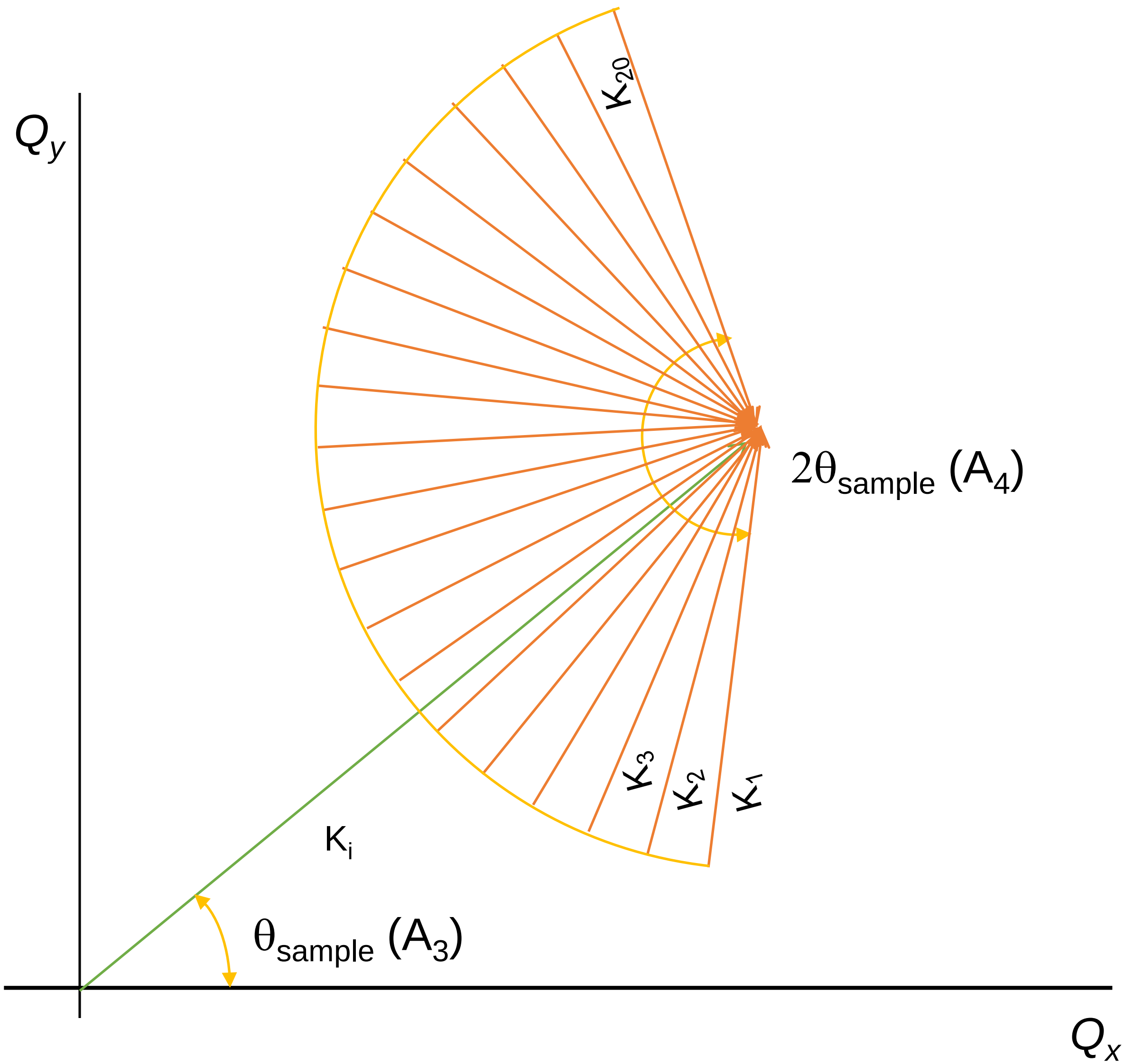

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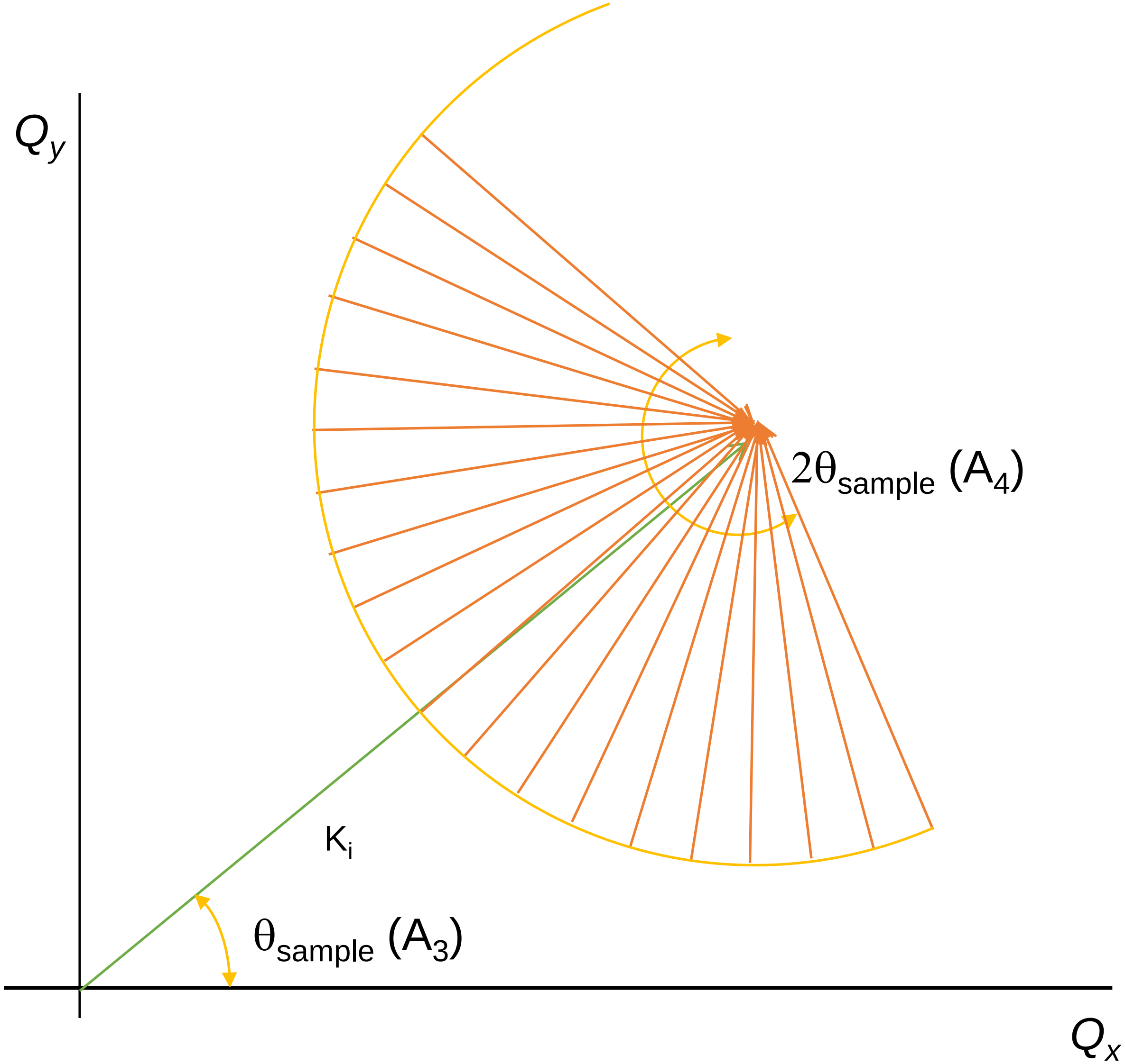

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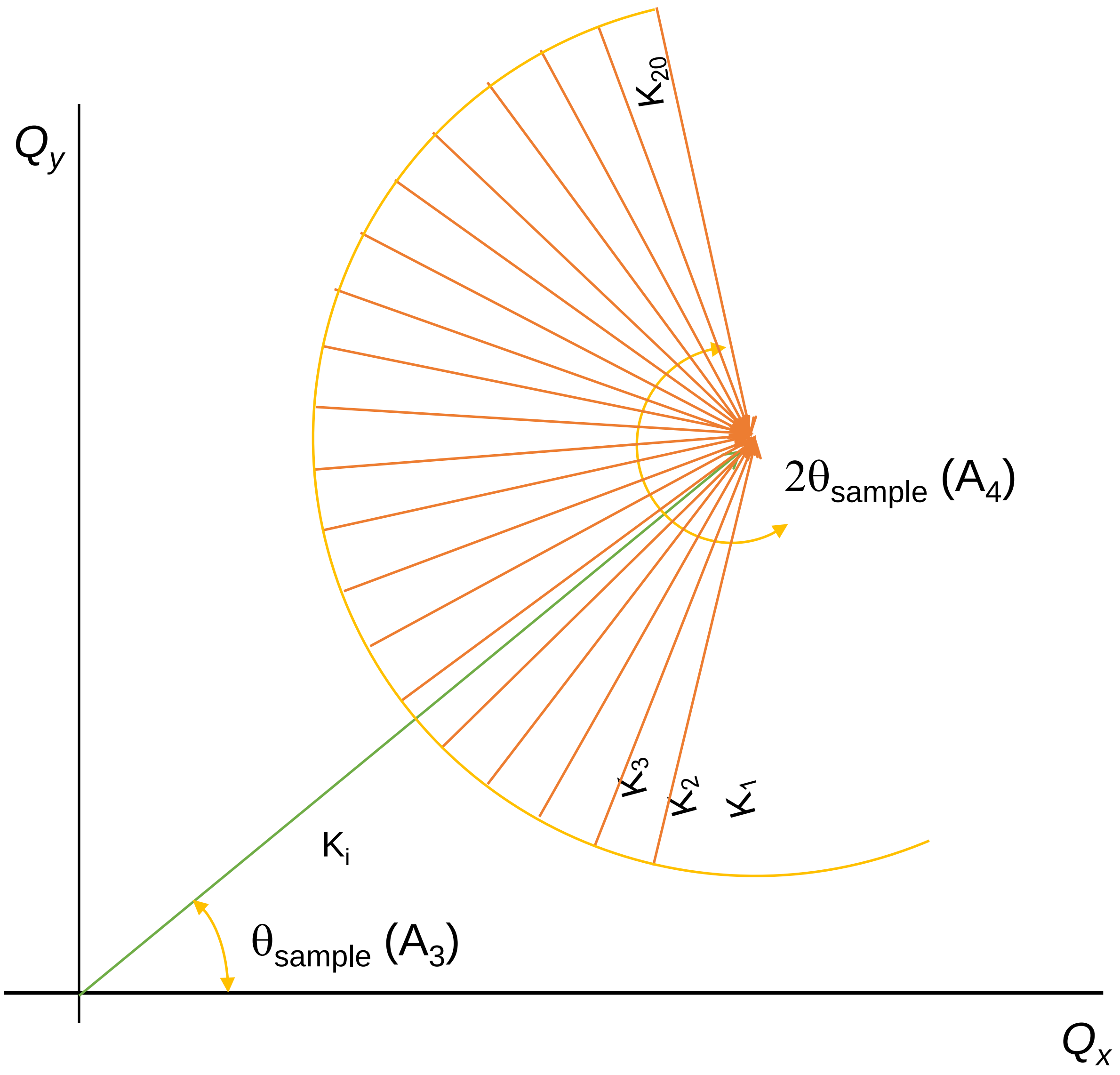

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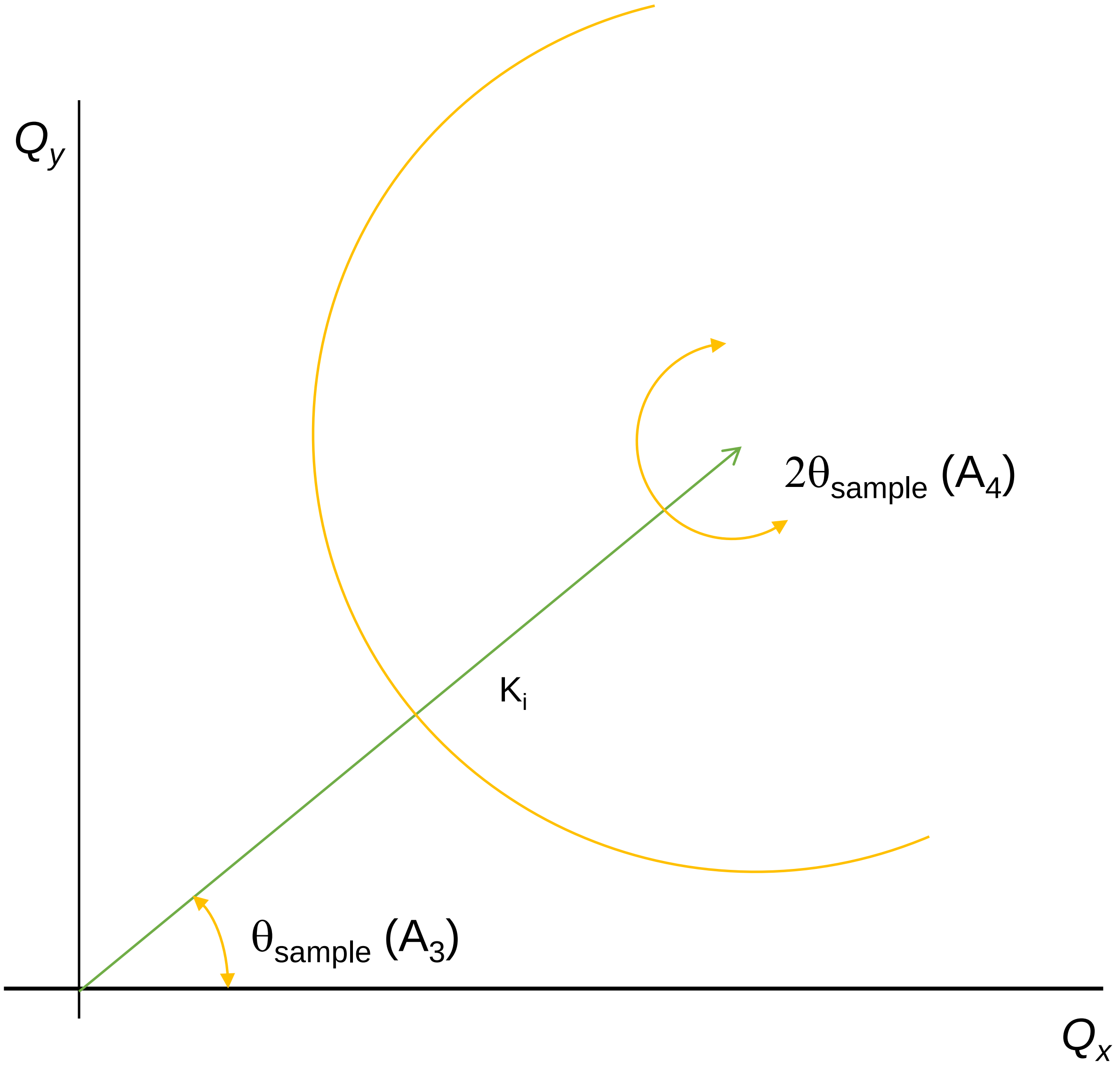

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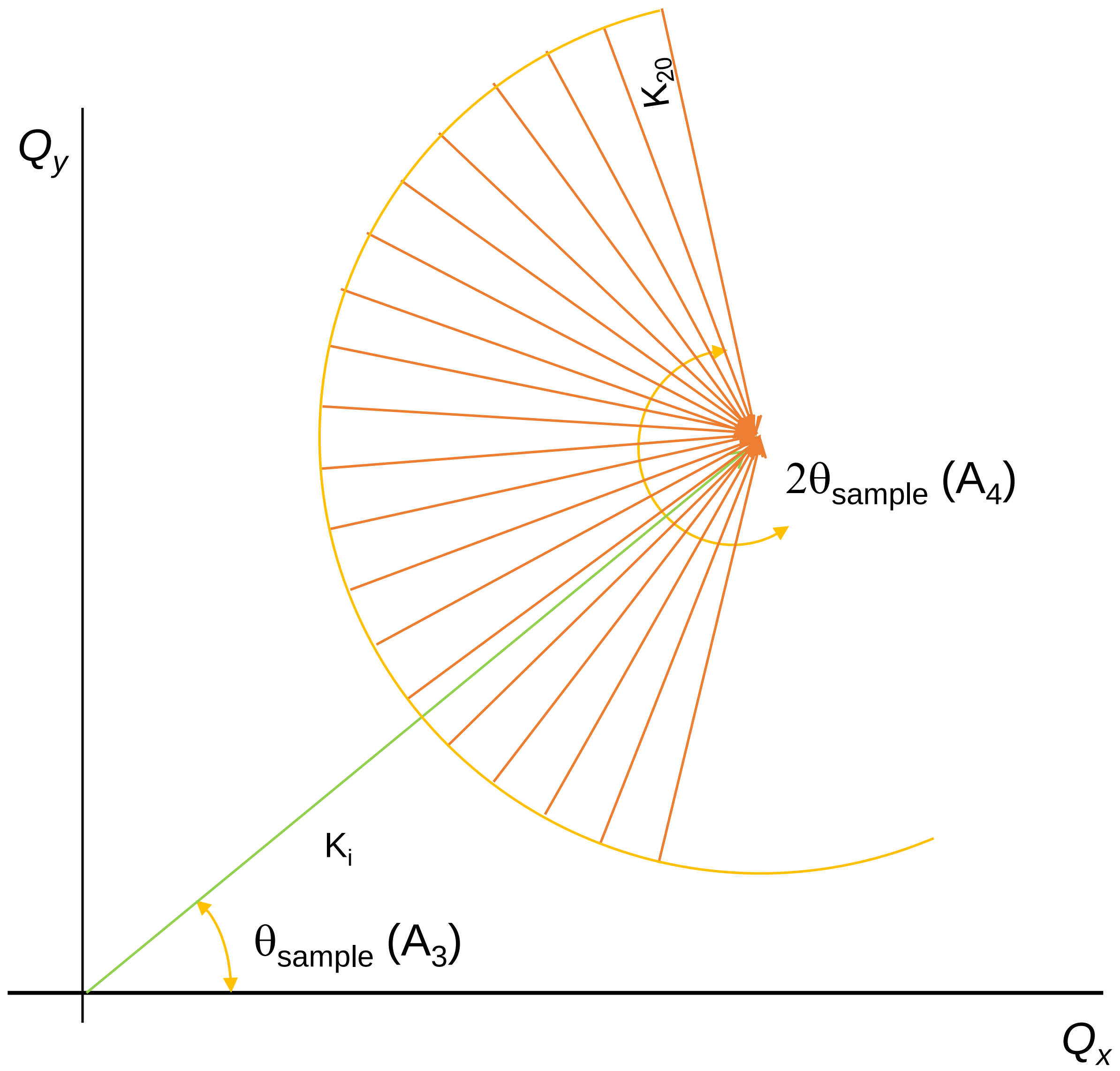

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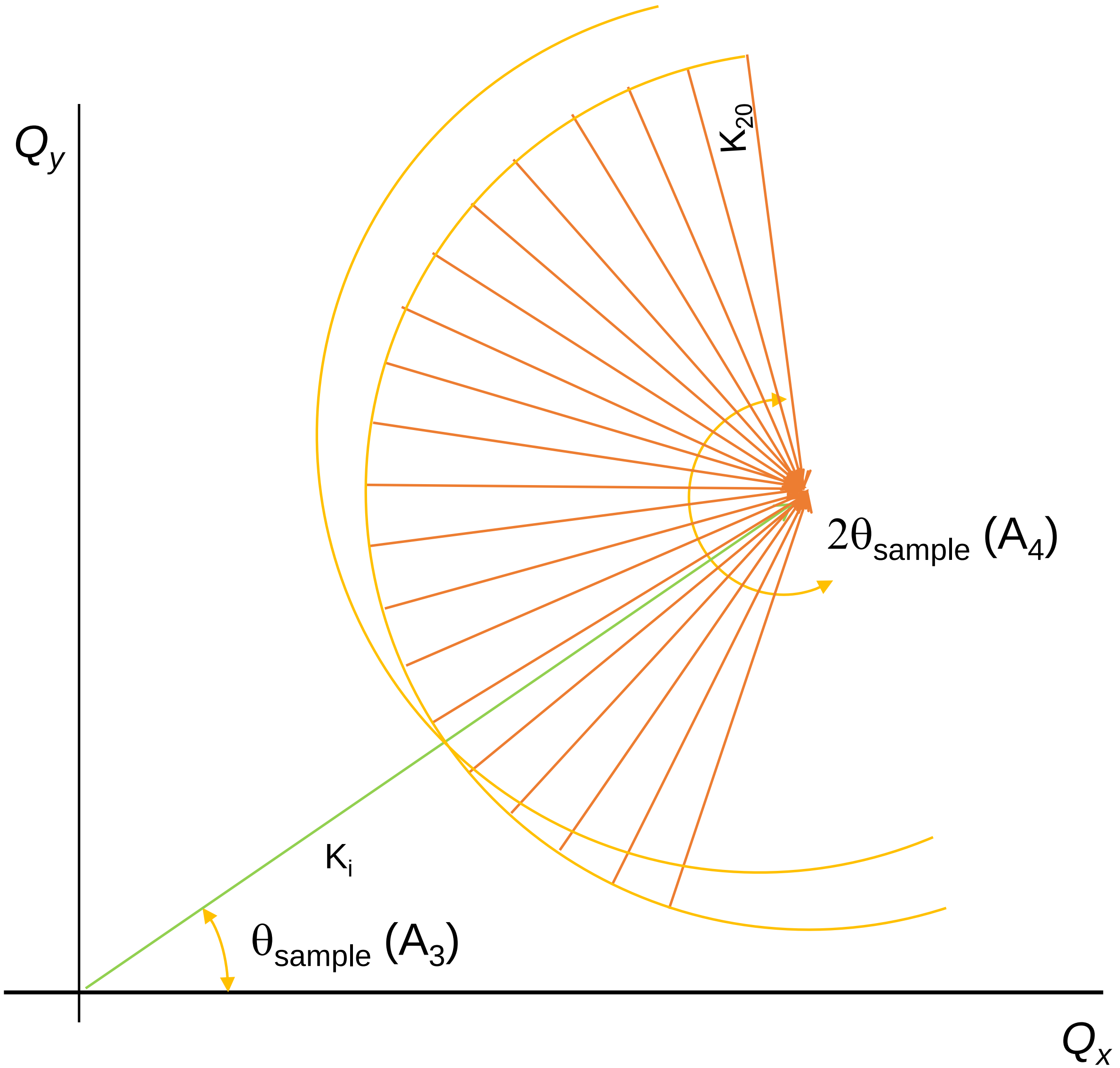

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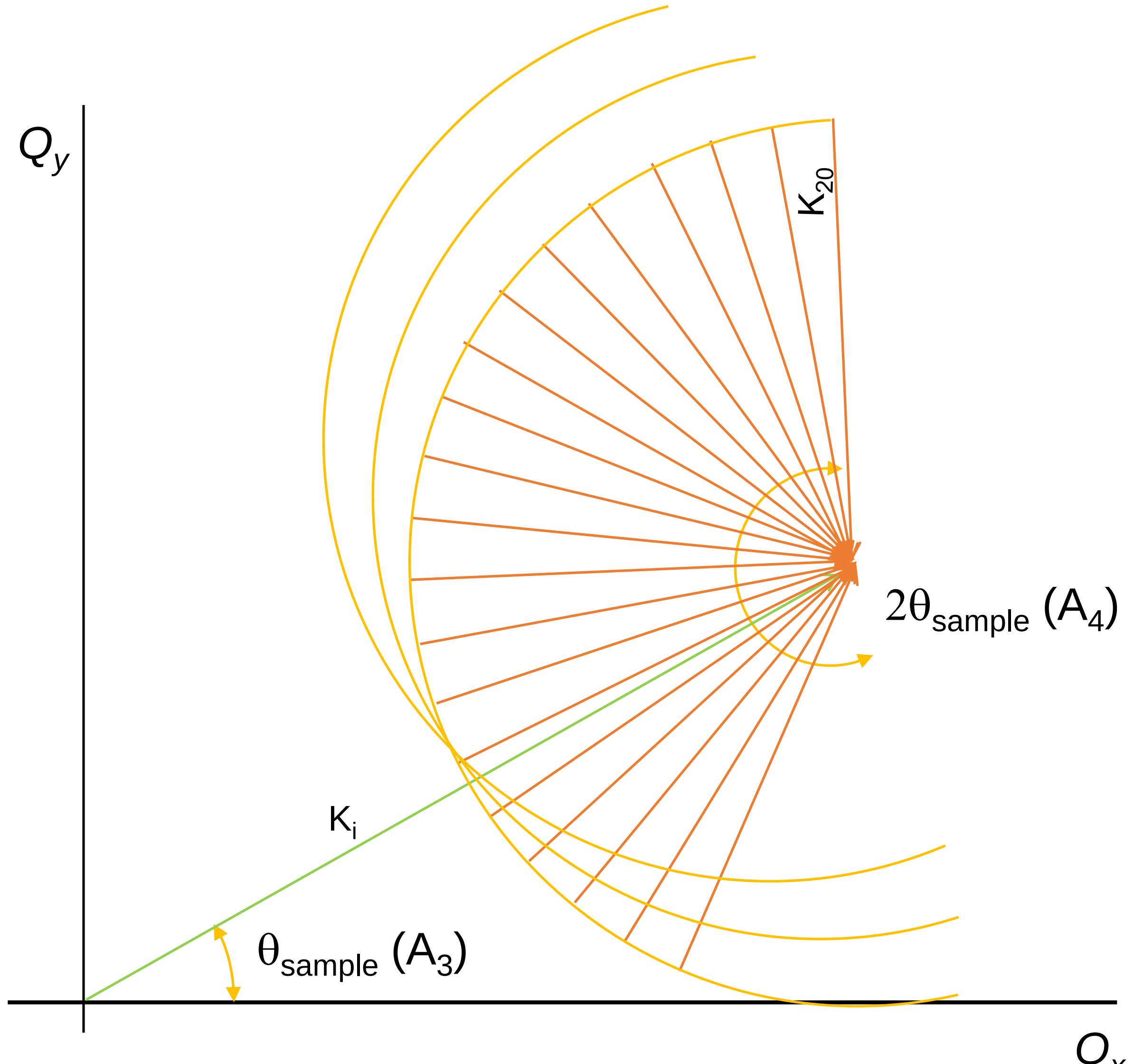

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