Magnetized States of Quantum Spin Chains

Collin Broholm
Johns Hopkins University and NIST Center for Neutron Research

- Zero field states of spin chains
  - S=1/2 "alternating" chain: Coupled spin dimers
  - S=1 chain: The Haldane singlet state
  - S=1/2 chain: Fermions on a string
- Magnetized States of spin chains
- Future experiments probing spin chains
  - Experiments that will probably be done with neutrons
  - Experiments that probably cannot be done with neutrons

Collaborators

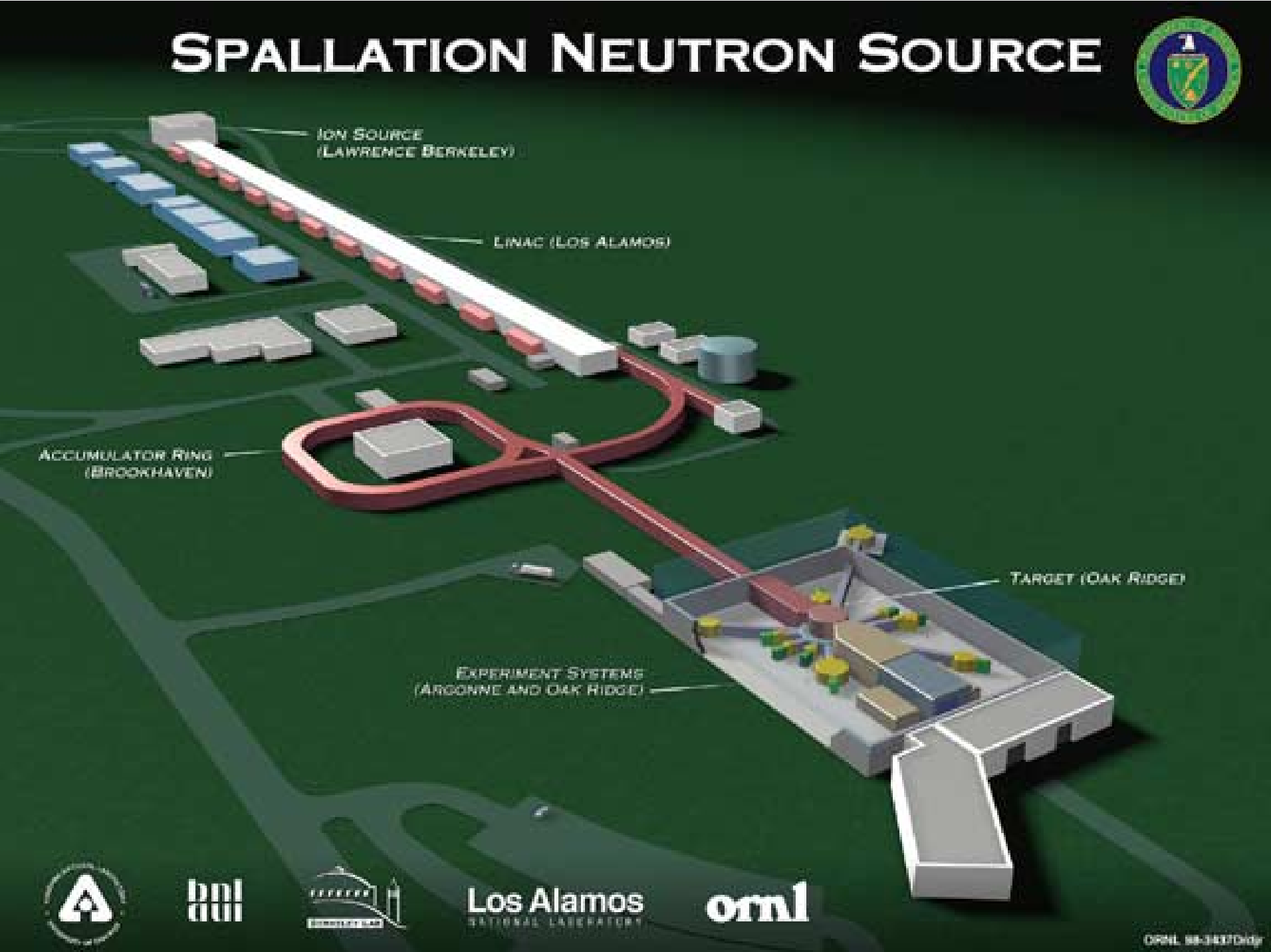
Crystal Growth and Bulk Measurements

C. P. Landee
T. Ito
H. Takagi
M. Turnbull
K. Oka

Scattering Experiments etc.

G. Xu
D. C. Dender
G. Aeppli
A. Tennant
G. Granroth
C. Frost
D. H. Reich
Matt Stone
P. Hammar
S. Nagler
M. Adams

SPALLATION NEUTRON SOURCE



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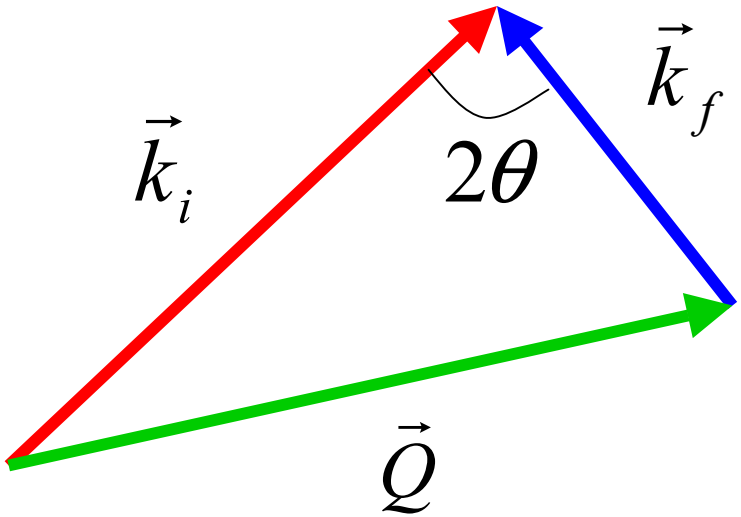
Magnetic Neutron Scattering



$$\vec{Q} = \vec{k}_i - \vec{k}_f$$

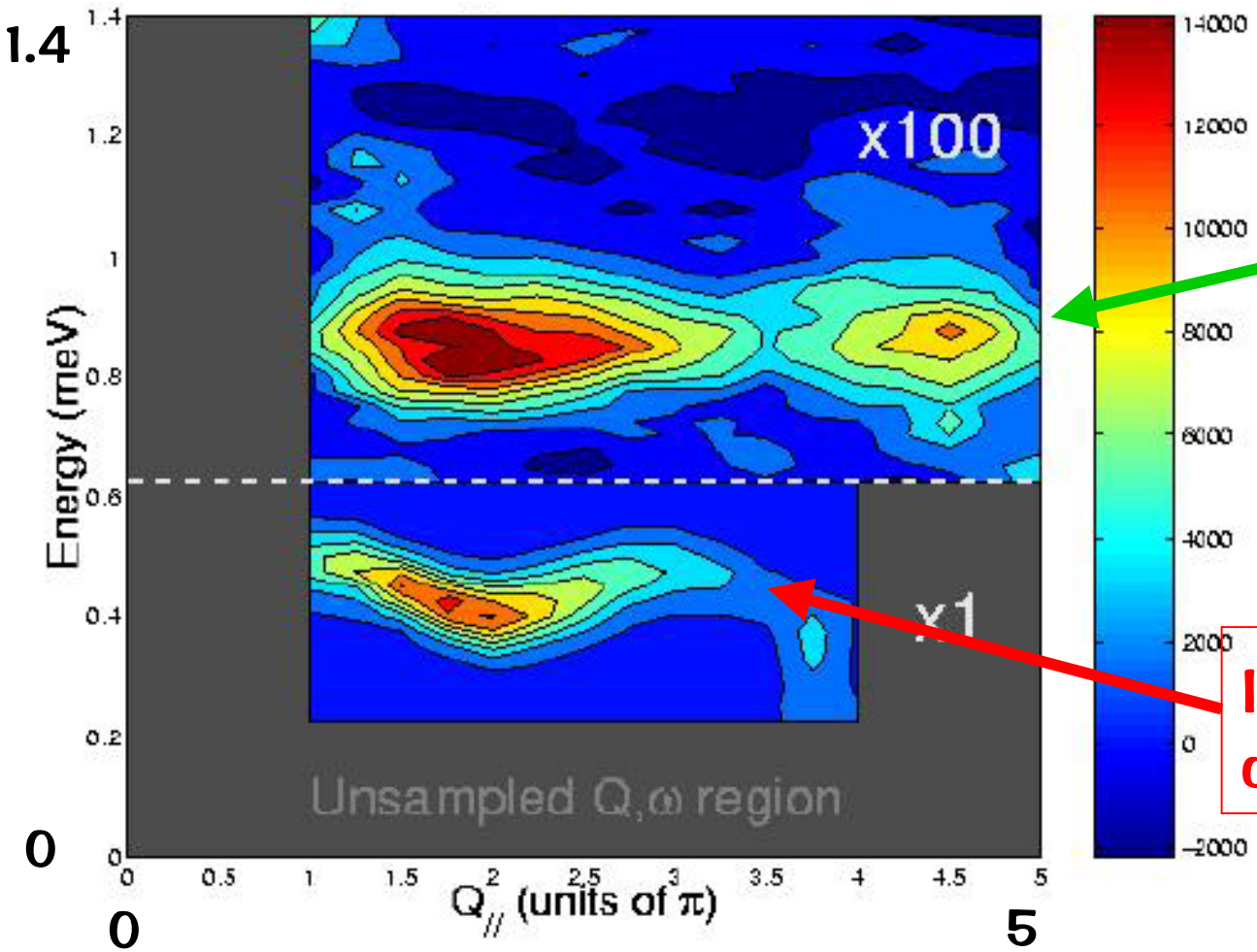
$$\hbar\omega = E_i - E_f$$

The scattering cross section is proportional to the Fourier transformed dynamic spin correlation function

$$\mathbf{S}^{\alpha\beta}(\vec{Q},\omega) = \frac{1}{2\pi\hbar}\int dt\; e^{-i\omega t}\,\frac{1}{N}\sum_{\vec{R}\vec{R}'} e^{i\vec{Q}\bullet(\vec{R}-\vec{R}')} < \mathrm{S}^{\alpha}_{\vec{\mathrm{R}}}(t)\,\mathrm{S}^{\beta}_{\vec{R}'}(0) >$$

Creating triplets on alternating spin-1/2 chain (α=0.27)

Copper Nitrate T=0.3 K

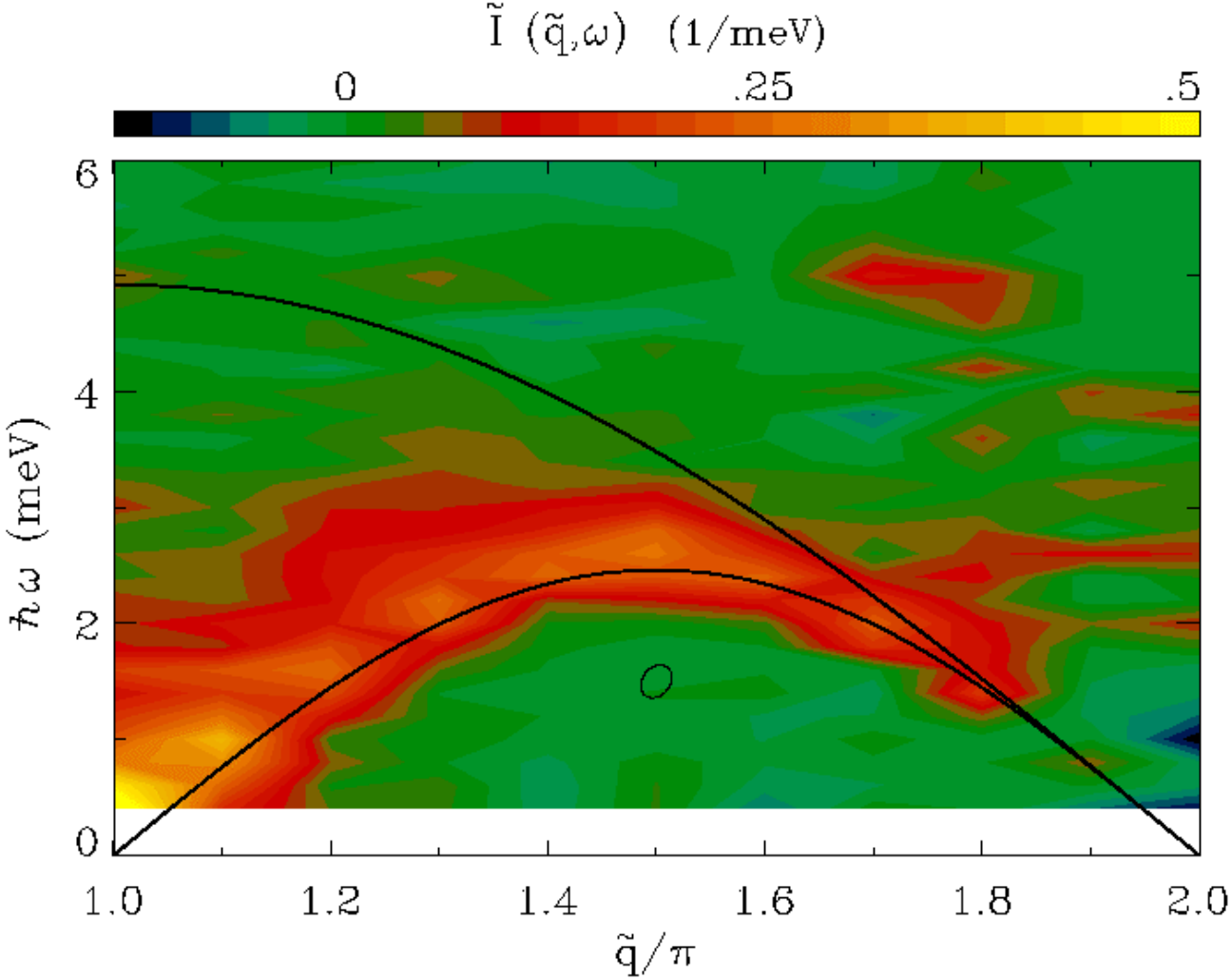


Triplet pair creation

Individual triplet creation as before

Xu et al 1998

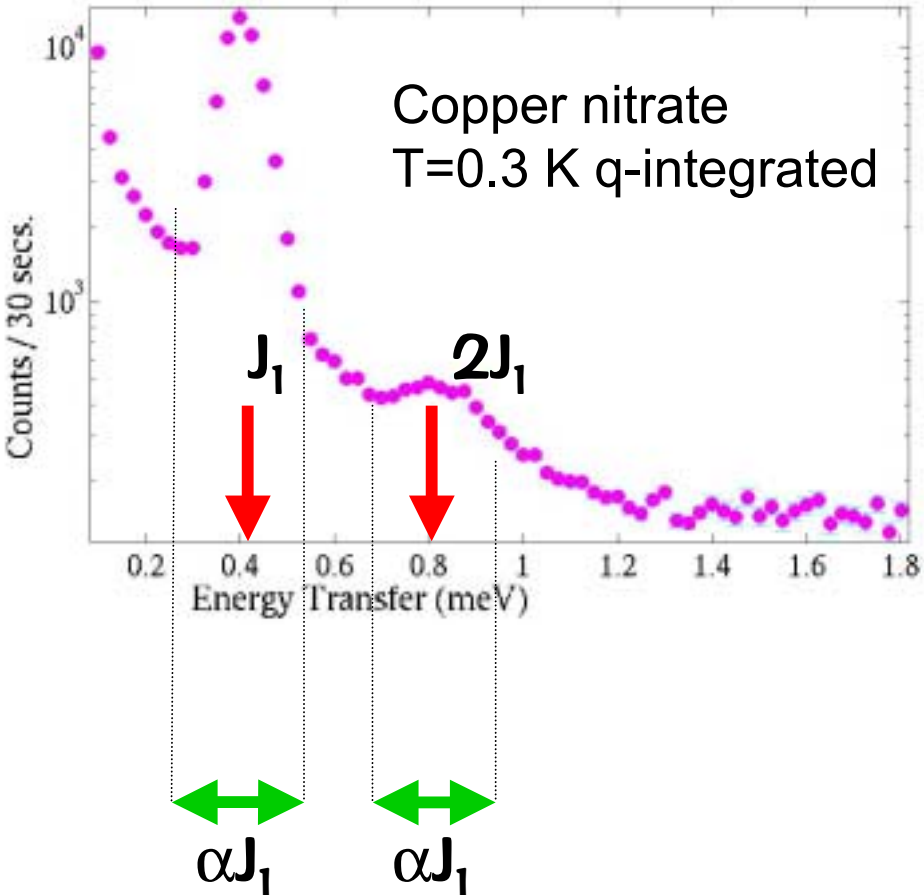
Gapless Continuum Scattering in Uniform spin-1/2 chain (α=1)



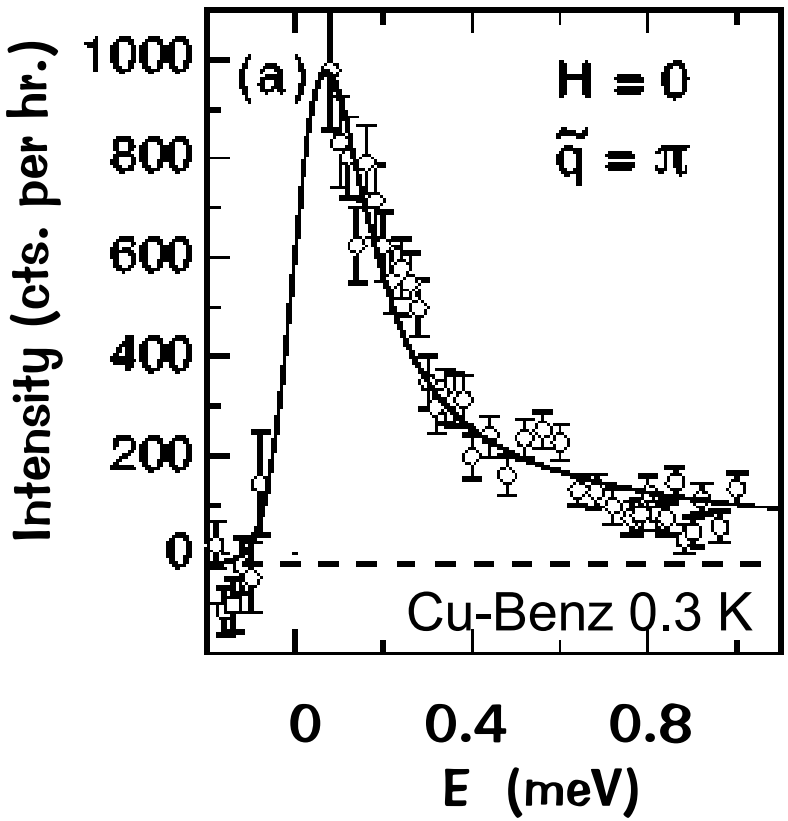
Copper benzoate
T=0.3 K
Dender et al. 1996

Spectrum for Alternating and Uniform spin-1/2 chains

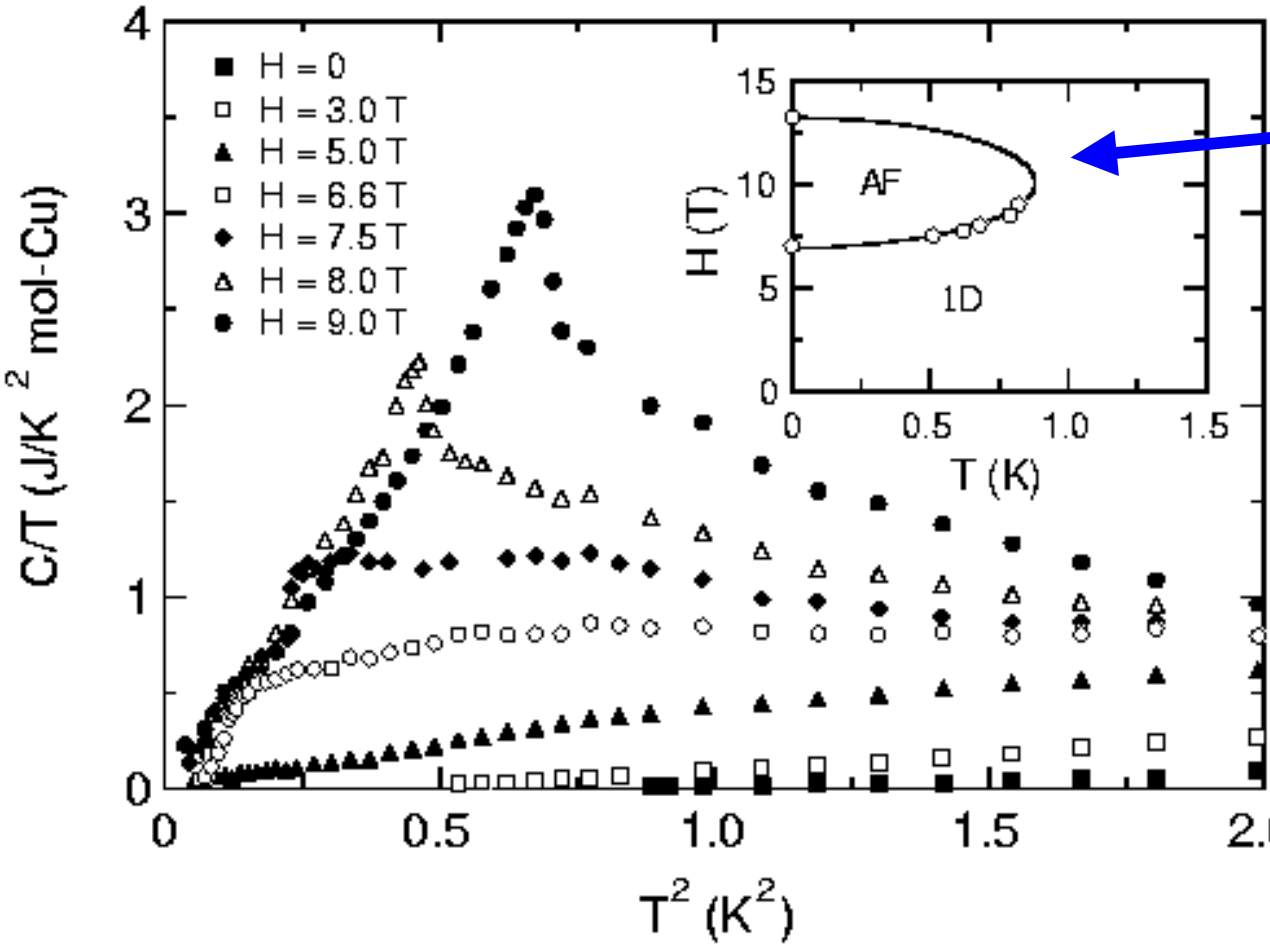
Spin gap and separated bands α=0.27



Gap-less continuum α=1



Field Induced Order in system of coupled spin-1/2 dimers (CuHpCl)



This may be incommensurate order with field dependent wave vector

Experimental Issues in Quantum Magnetism

- Characterize incommensurate magnetized states of spin systems with zero field macroscopic quantum singlet ground states.
- What effects come from doping spin chains?
- What are the critical properties of T=0 phase transitions between magnetic and non-magnetic states?
- Explore coherent transport of triplet wave packets along a quantum spin-chain.
- How does a quantum spin chain develop thermodynamic equilibrium from a non-equilibrium state?

The type of Experiments that will probably be done with neutrons

- Characterizing bulk magnetic excitations in materials that can be obtained as cm^3 sized single crystals.

- Solving magnetic structures when we have mm^3 sized single crystals, $P<30$ kbar, $B<12$ T, and we need only $\delta q>0.01$ A^{-1}.

The type of Experiments that will probably not be done with neutrons

- Elastic and inelastic experiments on surfaces, sub mm^3 samples, or samples that absorb neutrons.
- Element or charge/orbital state specificity required.
- Experiments that require high q-resolution ($\delta q < 0.01$ A^{-1})
- Experiments that probe spin systems away from thermal equilibrium (time and direct spatial resolution).
- Experiments on magnetic samples under extreme conditions of pressure (P>25 kbar) or magnetic field (B>12, 15, 30 T?).