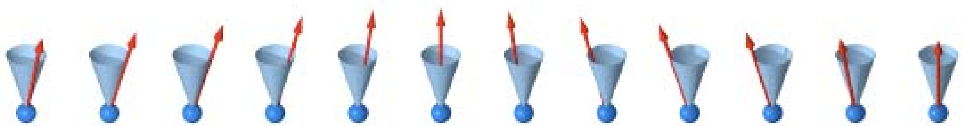
BT-7's GroupiEs:

Adventures in Spin Waves

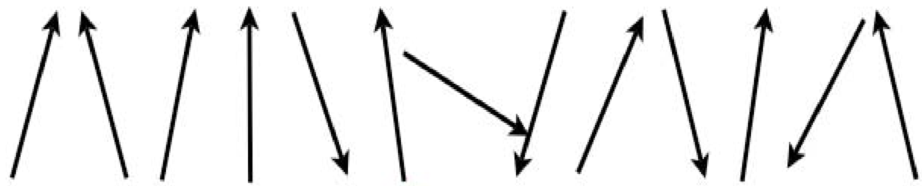


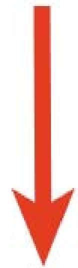
Alice
Corneliu
Kate
Keeseong
Miaoying
Vivek
Xi

Presented by Group E
NCNR Summer School 2009

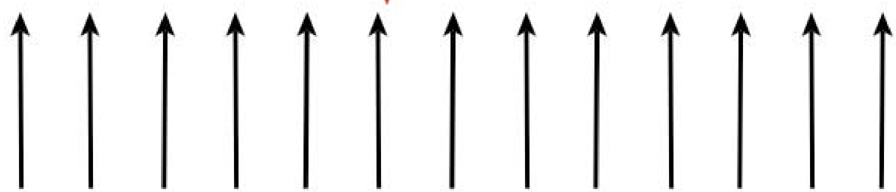
Jeff Lynn
William Ratcliff
Songxue Chi

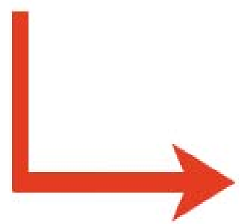
Magnetic Order and Dynamics

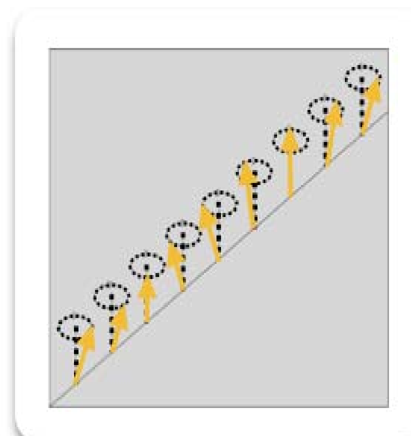




Cool down
through phase
transition

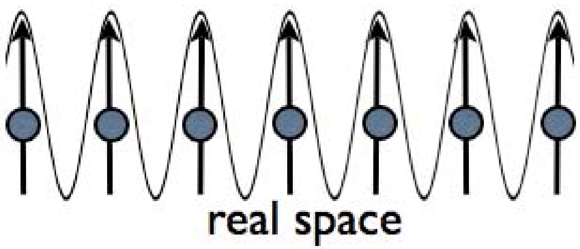




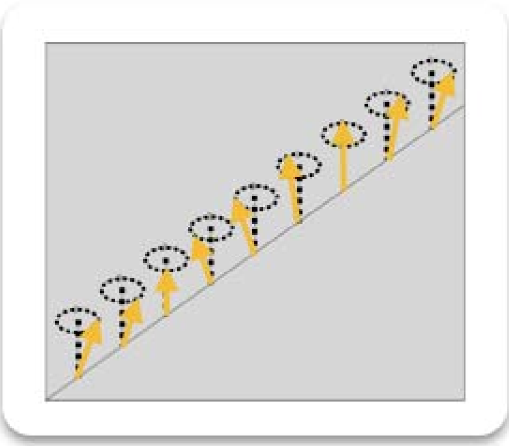


Give it a kick!
You get spin a
spin wave

Neutron Scattering in a Ferromagnetically ordered State

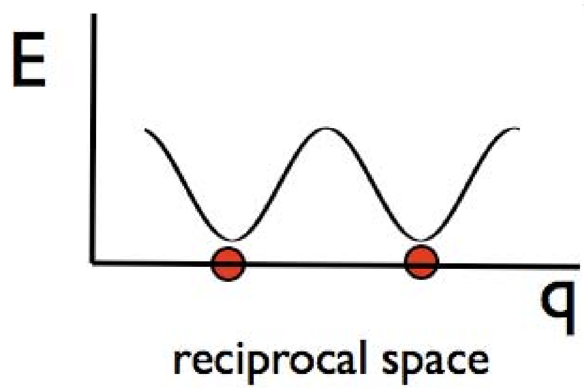


Static order : **Elastic Bragg Peaks**



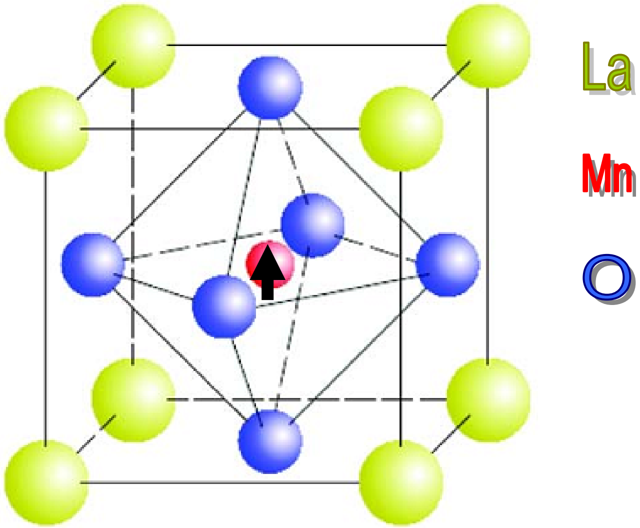
Dynamics: The spin waves follow a **dispersion curve**

- They have a specific energy at each momentum transfer E(q)
- Use **Inelastic Scattering** to measure it!

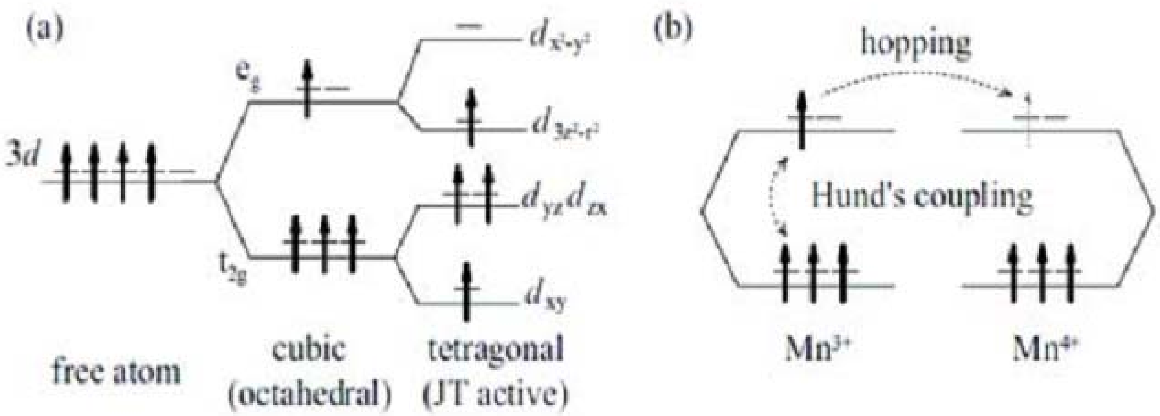


Colossal magnetoresistance manganites

- **$LaMnO_3$** – model system for manganites
- Crystal structure – cubic perovskite system

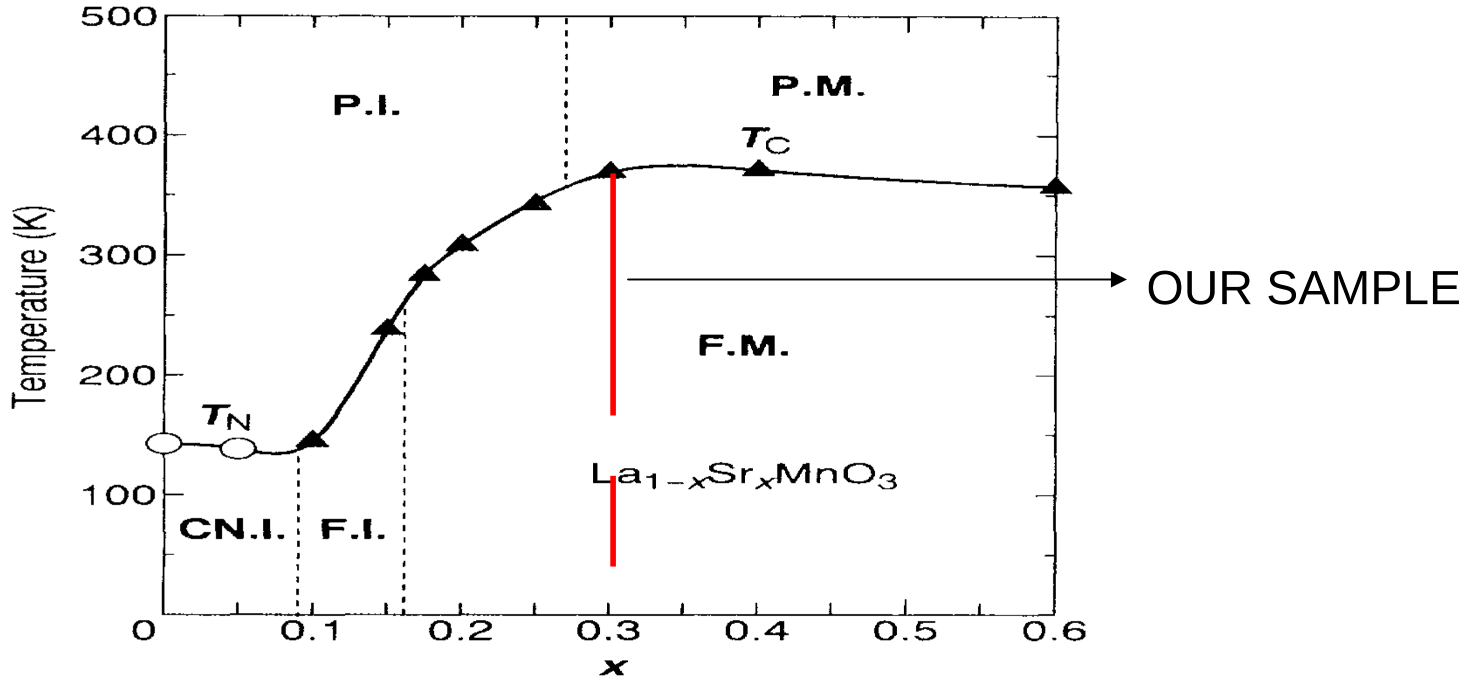


- Electronic configuration of Mn d orbitals:



$LaMnO_3$ —**Sr^{2+}** doping→ **$La_{1-x}\,Sr_x\,MnO_3$**

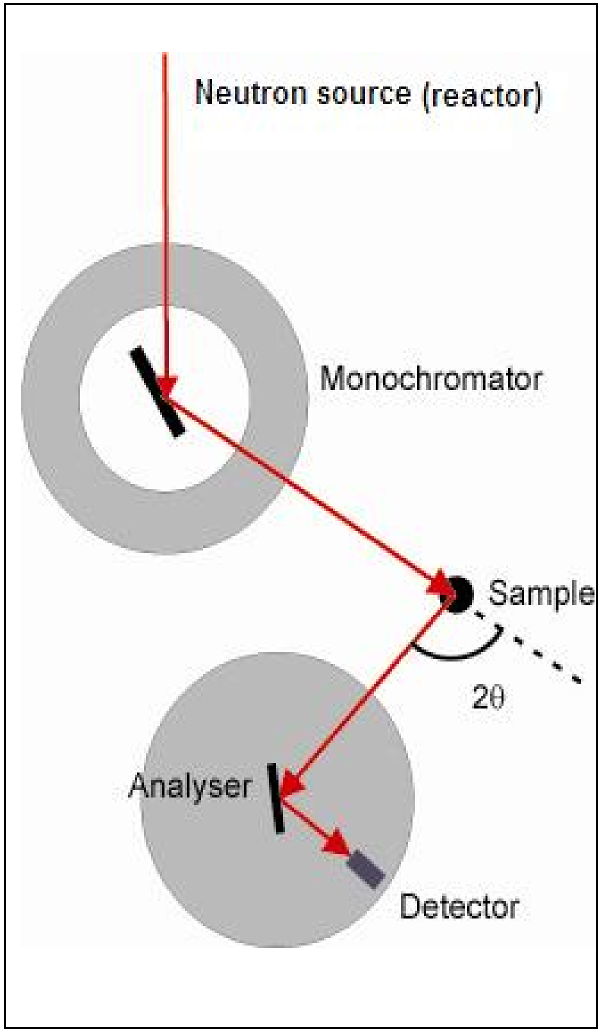
Magnetic and metal - insulator transition in $LaSrMnO_3$

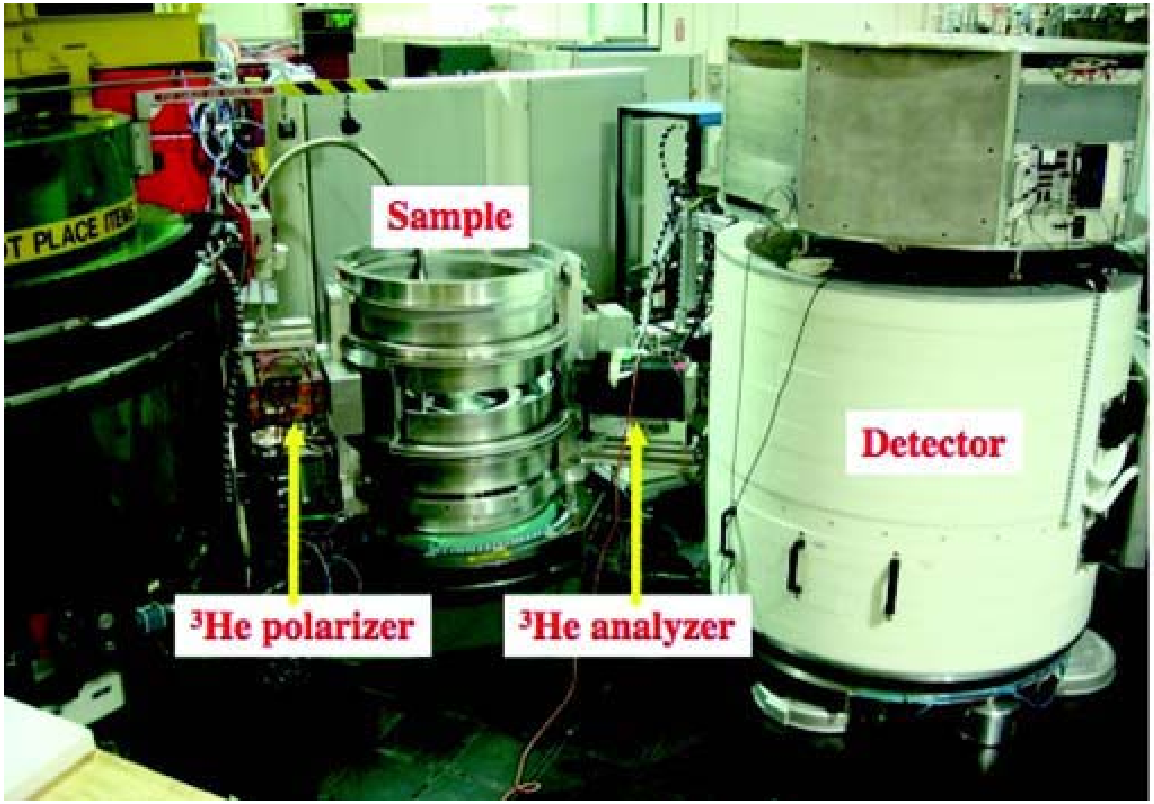


• We used neutrons to study the ferromagnetically ordered state at this doping level

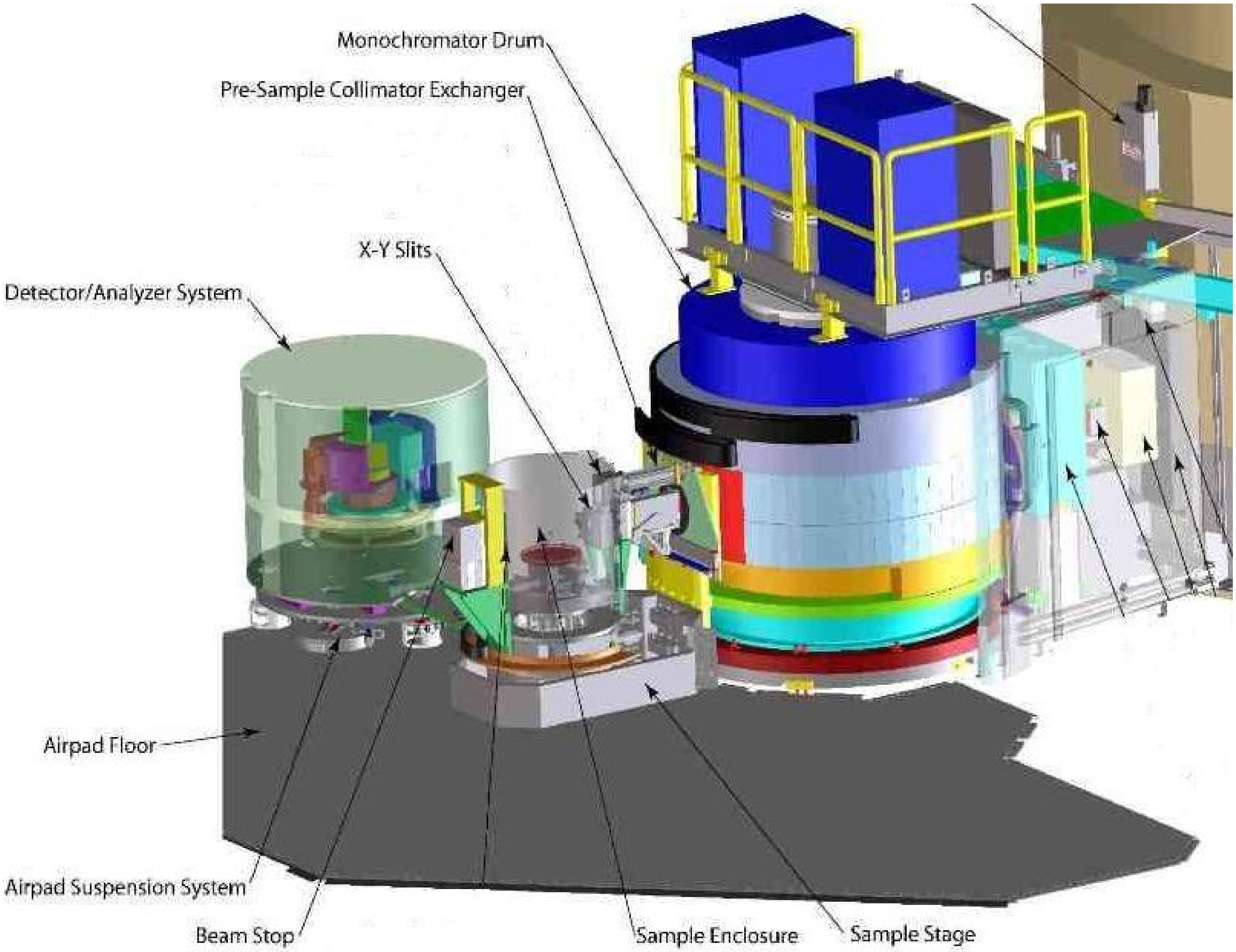
BT7 Triple-Axis Spectrometer

Schematic

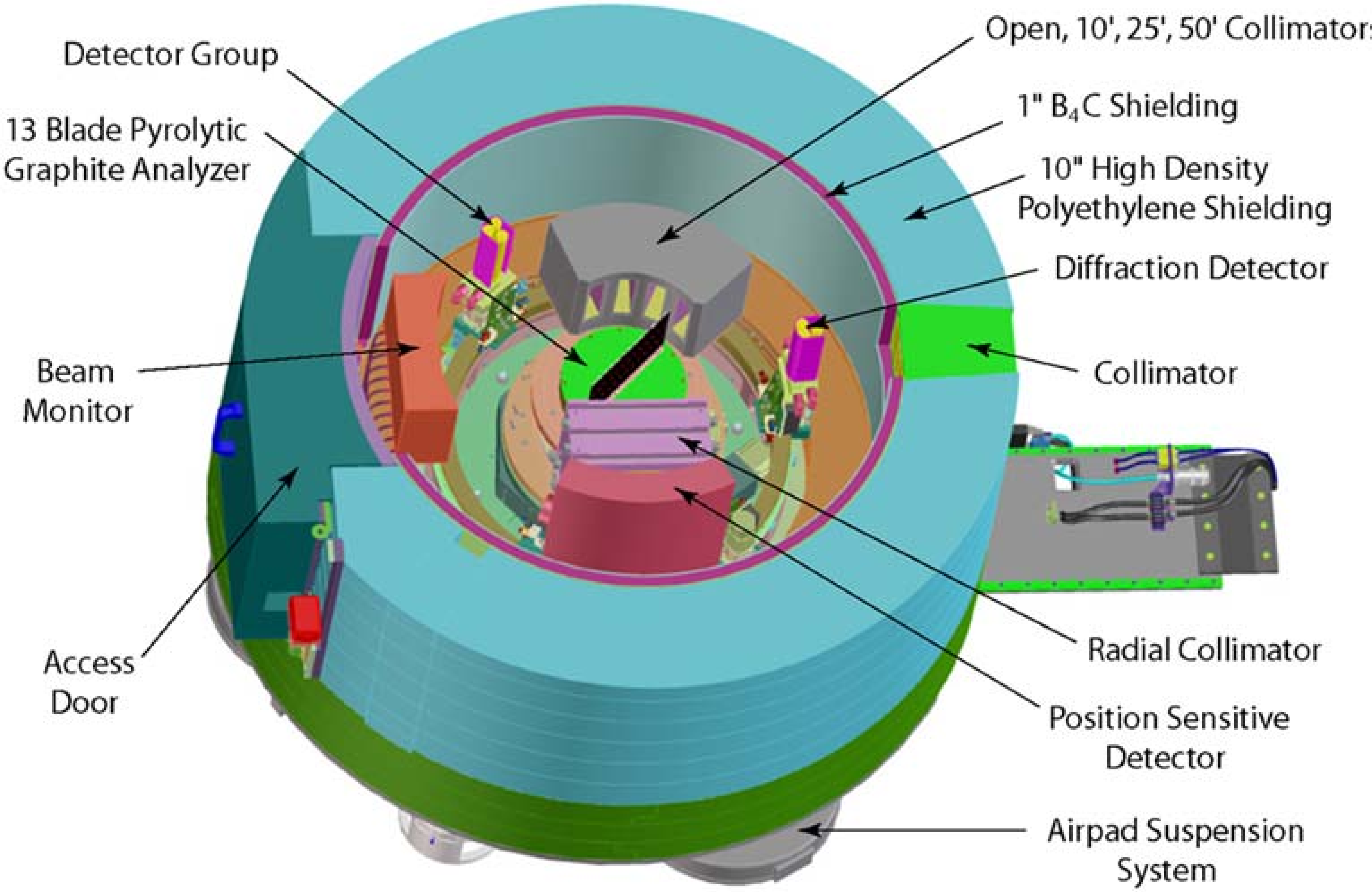




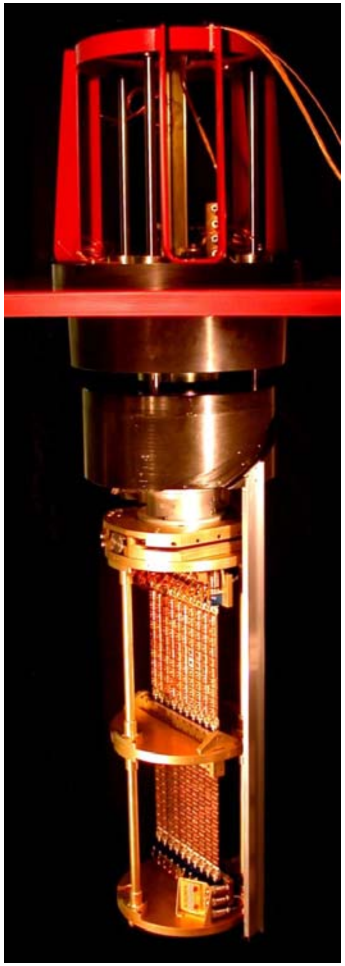
BT7 Triple-Axis Spectrometer

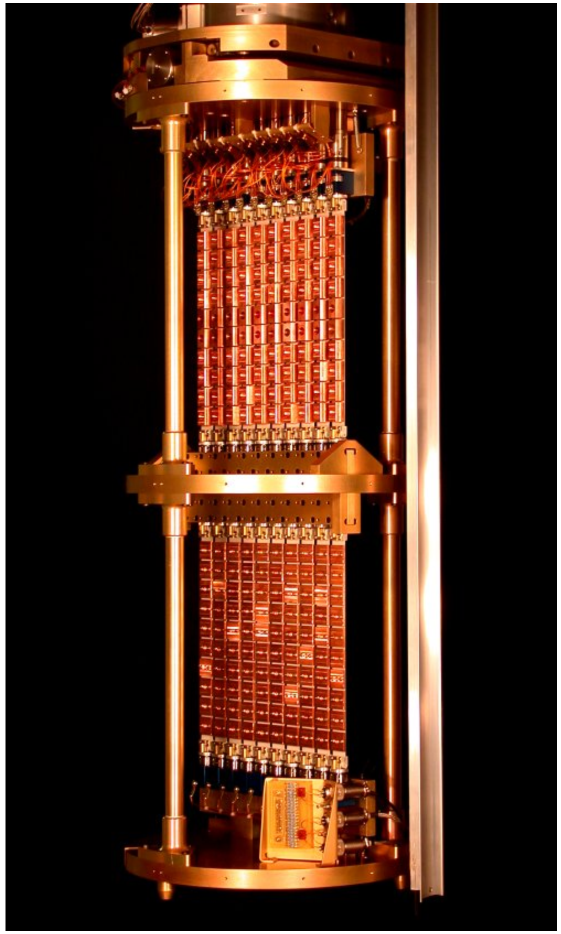


BT-7 Detector/Analyzer Array

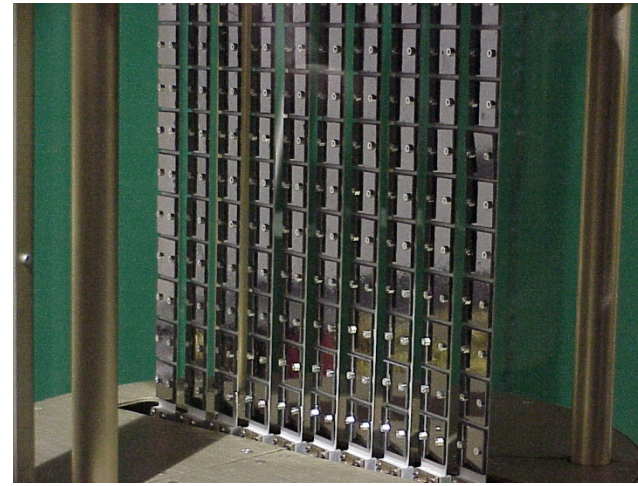


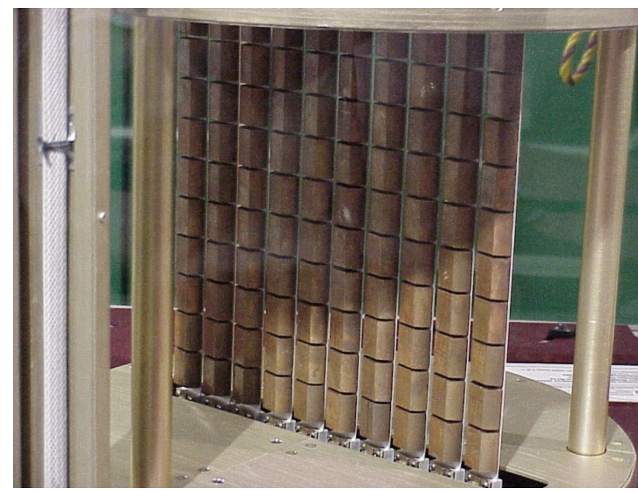
Monochromator Arrays





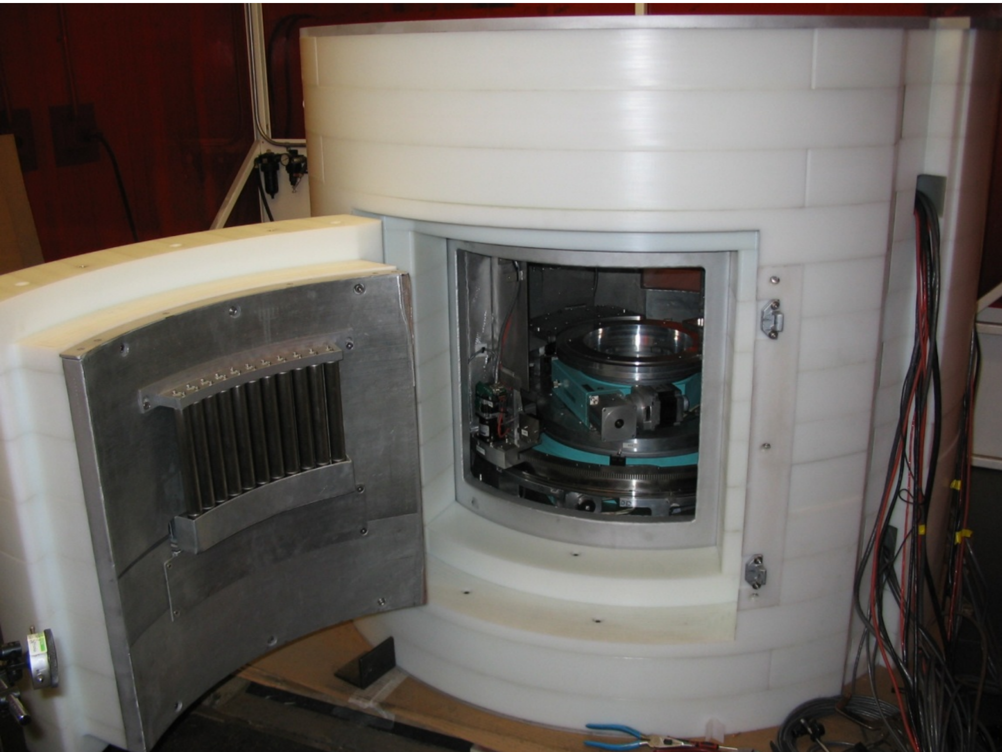
Cu(220) d = 1.27 Å





PG(002) d = 3.35 Å

Analyzer System



SPINS vs. BT7

"Cold" neutrons

Lower energy (0.1 – 10 meV)

Monochromator:

- 5 blades of PG (Pyrolytic Graphite) crystals.
- vertical focusing only

Analyzer – 11 blades of PG crystals

Better for small, higher resolution Q measurements

Experiment:

Studying magnetic correlations in the geometrically frustrated AF $CdCr_2O_4$

"Thermal" neutrons

Higher energy (5 – 500 meV)

Monochromator:

- 10 blades of PG or Cu crystals
- double focusing (horizontal AND vertical, so good for flux measurements)

Analyzer – 13 blades of PG crystals

Better for high Q measurements

Experiment:

Studying magnetic phase transition and spin wave excitations in the perovskite $La_{0.7}Sr_{0.3}MnO_3$

Data and Analysis

Dispersion Relation

Hamiltonian: $H = -\frac{1}{2}\sum_{i,j} J_{i,j}\vec{S}_i \bullet \vec{S}_j$

Assume nearest-neighbor exchange only, =>

$$E_{sw} = 8SJ\sin^2(qa/2)$$

Small-q spin wave, => $E_{sw} = 2JSa^2q^2$

Note: $\mathrm{E} \rightarrow 0$ as $\mathrm{q} \rightarrow 0$ => isotropic ferromagnet

Taylor expansion: $E_{sw} = \Delta(T) + D(T)q^2 + E(T)q^4$

The Measurement

- “Constant q” scans
- change the analyzer to scan through energy
- then change q and repeat!
- Can fit the peaks to find their centers and full widths
- peak position changes at different q’s → DISPERSION!

The Measurement

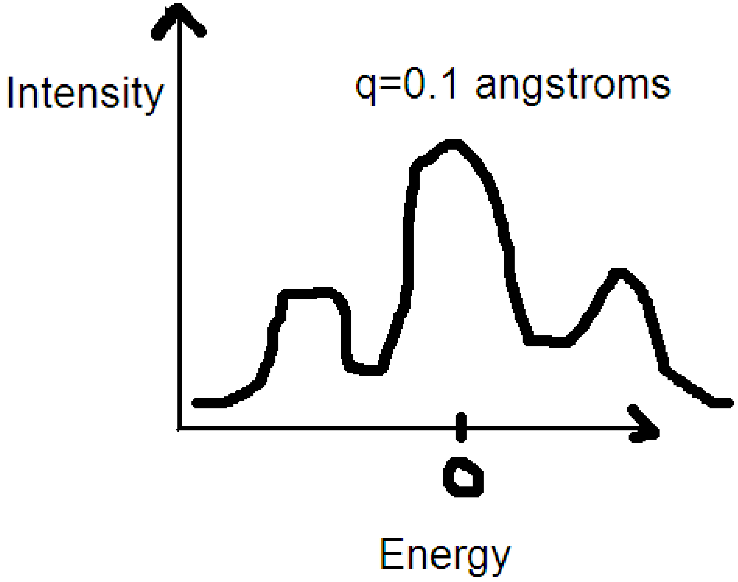
•"Constant q" scans

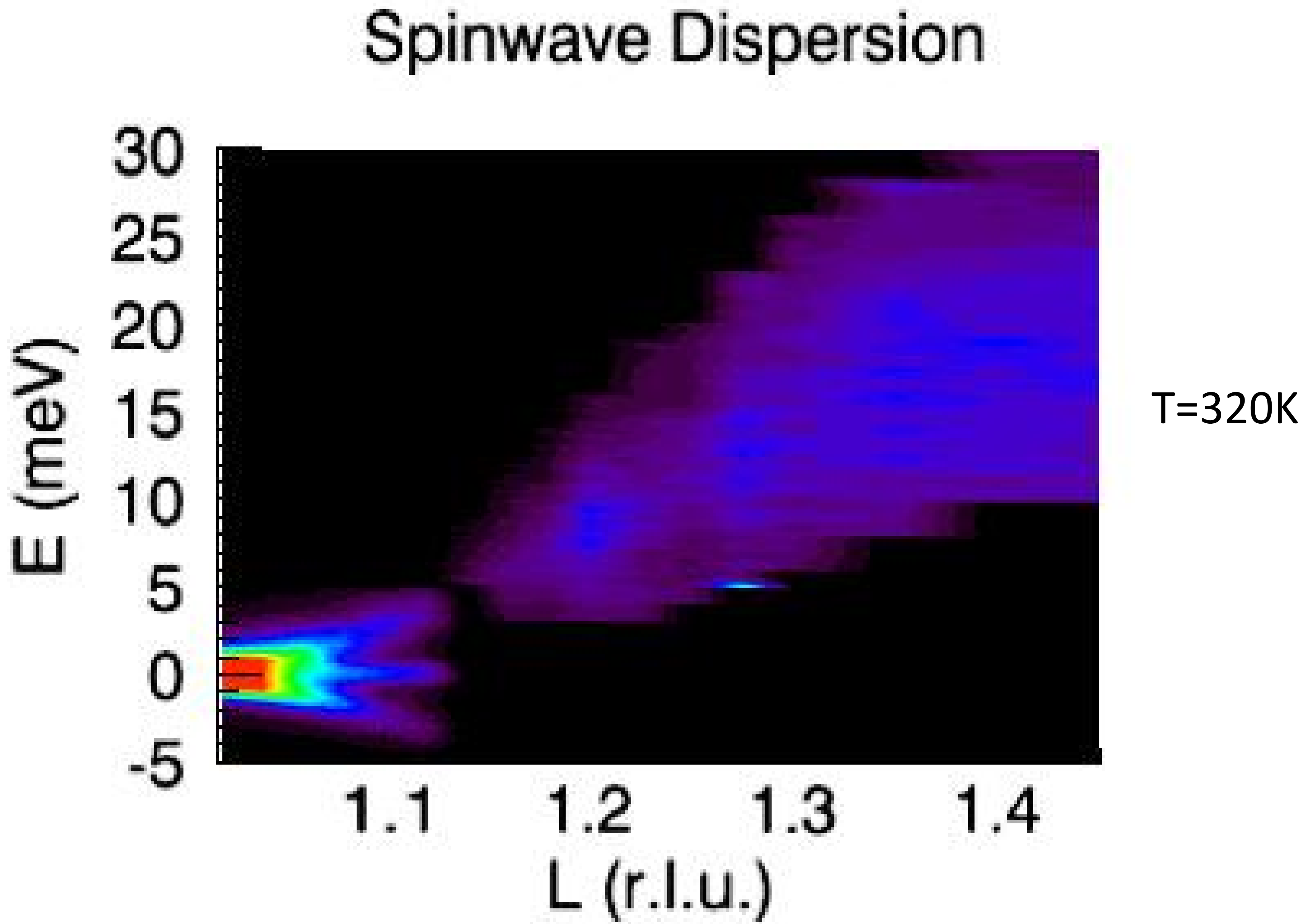
•change the analyzer to scan through energy

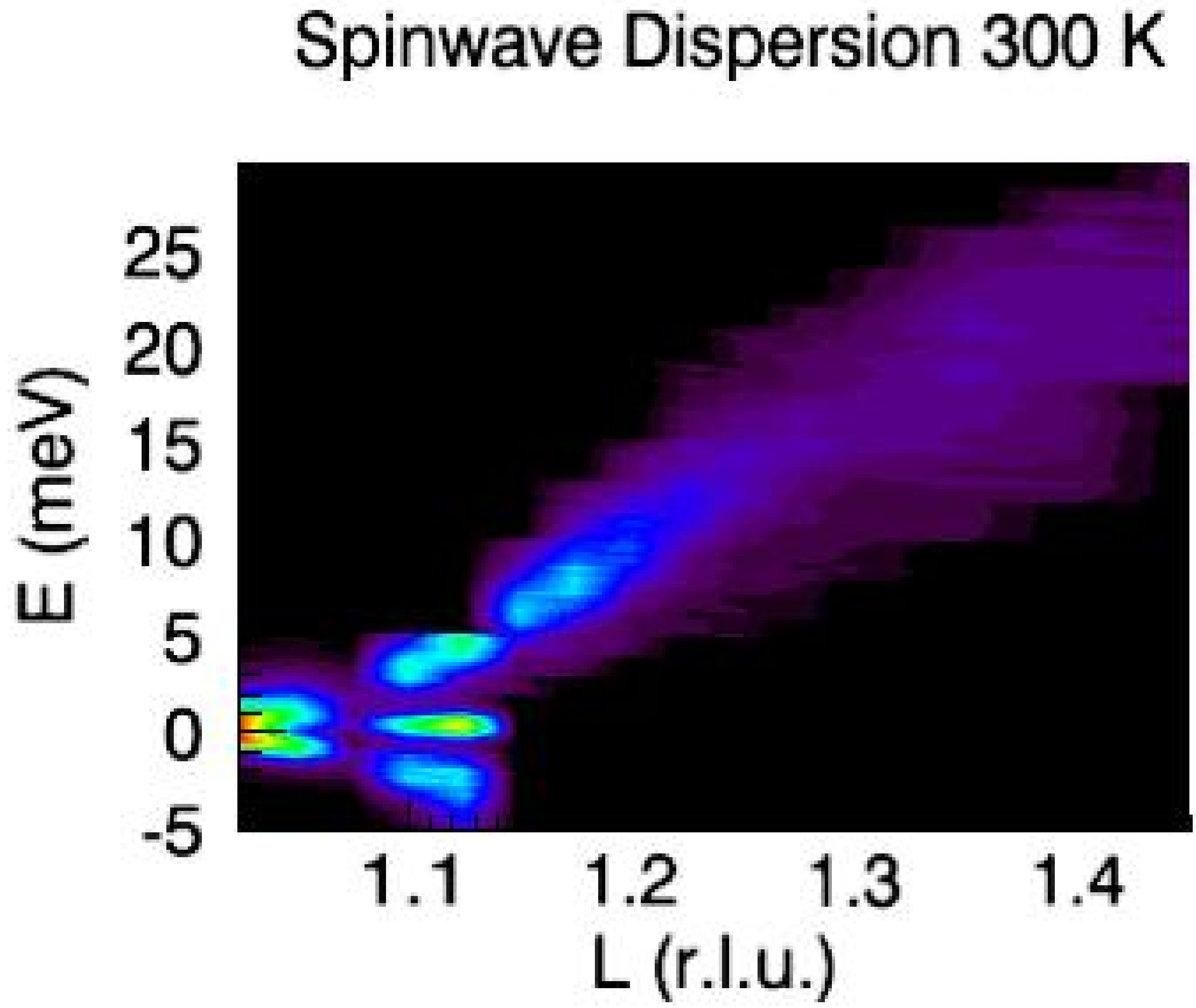
•then change q and repeat!

•Can fit the peaks to find their centers and full widths

•peak position changes at different q's → DISPERSION!



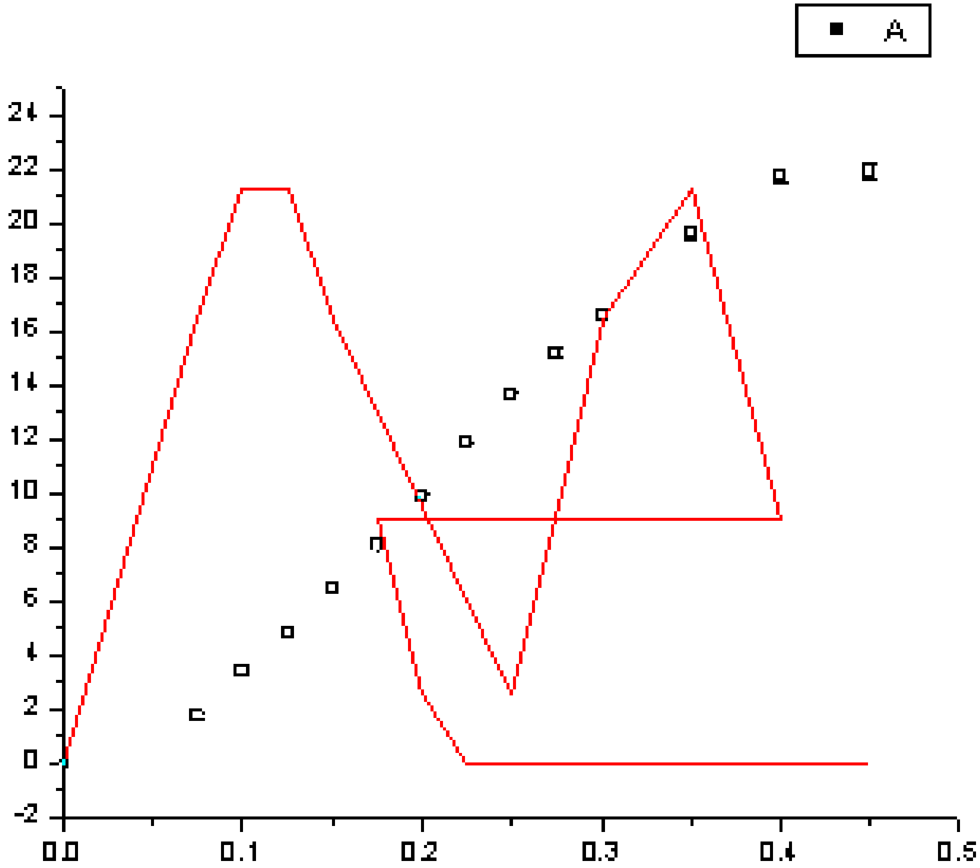

Spinwave Dispersion
E (meV)
30
25
20
15
10
5
0
-5
1.1
1.2
1.3
1.4
L (r.l.u.)
T=320K



T=300K

Dispersion Relation

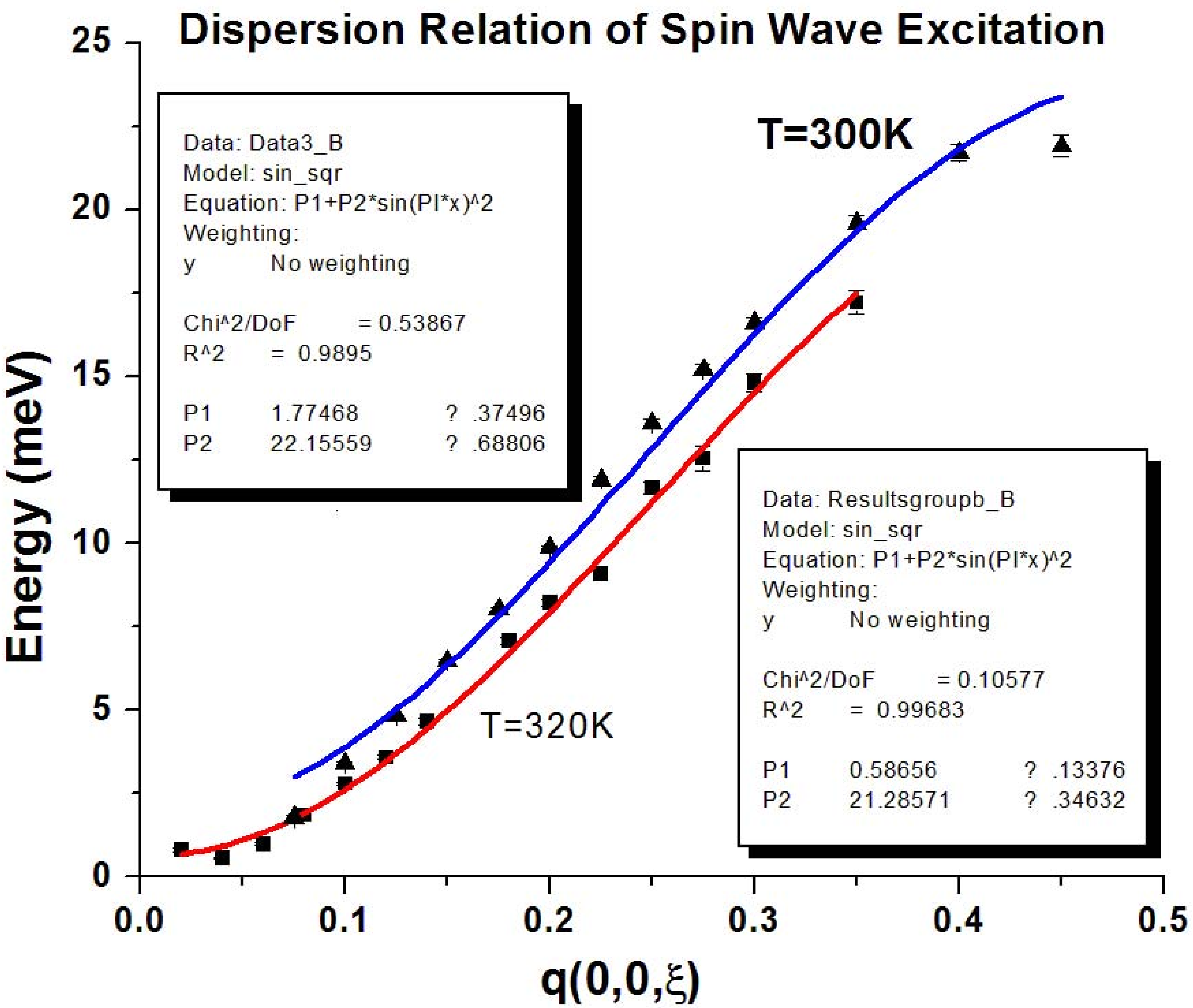
Energy (meV)

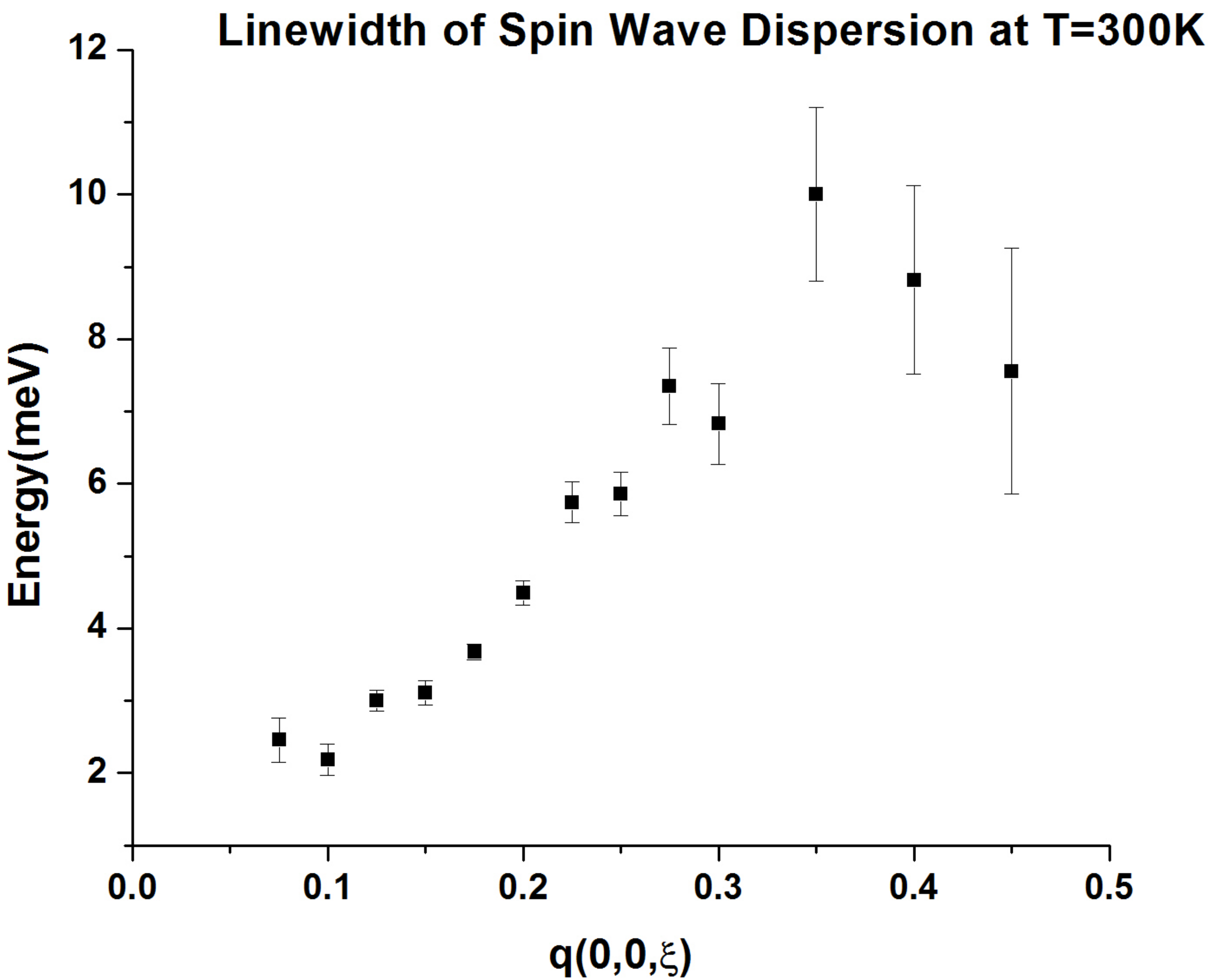


chi^2 = 88,000

q

Dispersion Relation





Linewidth of Spin Wave Dispersion at T=300K
Energy(meV)
12
10
8
6
4
2
0.0
0.1
0.2
0.3
0.4
0.5
q(0,0,ξ)

Conclusion

BT7 → Thermal neutron Triple axis spectrometer

$La_{0.7}Sr_{0.3}MnO_3$ → Colossal Magnetoresistive Materials

Inelastic Neutron Scattering

→ Dispersion relation of $La_{0.7}Sr_{0.3}MnO_3$

→ Critical Scattering (Tc~360K)

Summer School → Cool!