Online Card

Multi-Axis Spectrometer

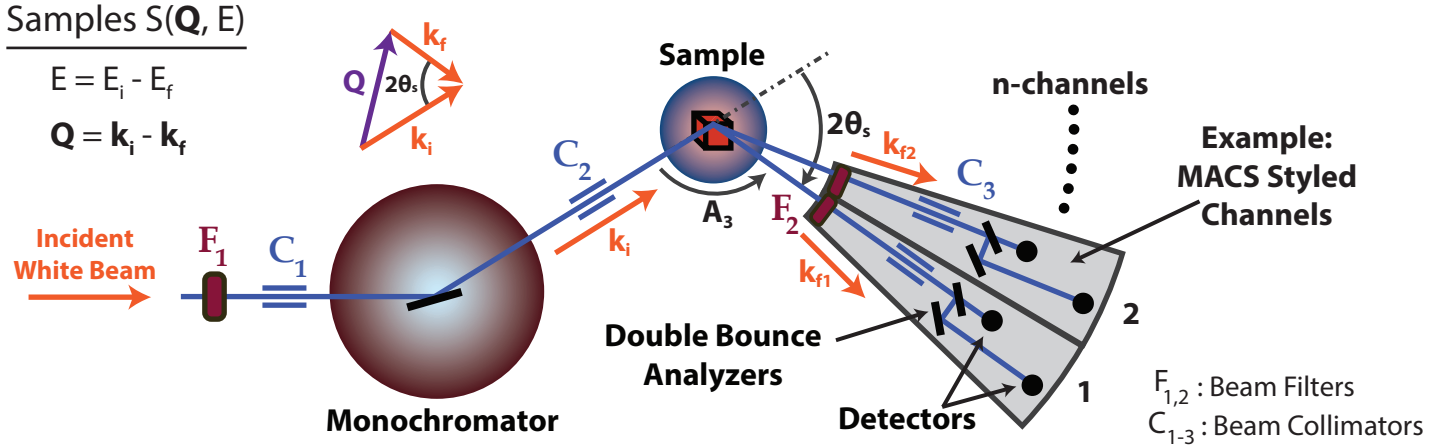
CHRNS NIST

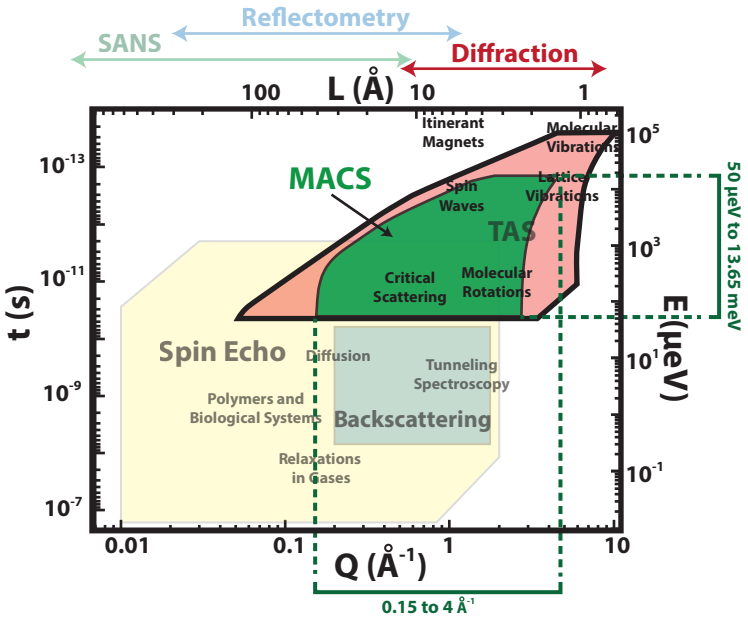
NIST CENTER FOR NEUTRON RESEARCH

Samples S(**Q**, E)

$E = E_i - E_f$

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





Operating Principles

1) The crystal monochromator and analyzer reflect neutrons with incident energy (E_i) and final energy (E_f).
   Elastic measurements ($E_i = E_f$): Resolves structure
   Inelastic measurements ($E_i \neq E_f$): Resolves excitations.

2) E_f is typically fixed for an experiment. Changing E_i selects the desired excitation energy: $E = E_i - E_f$

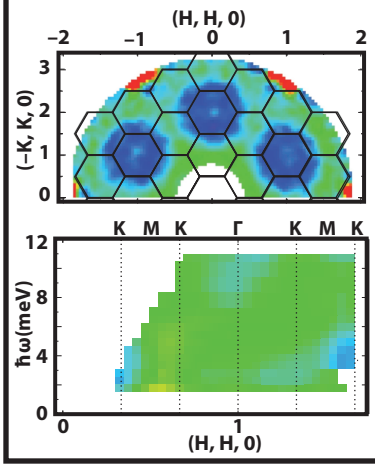
3) Rotation of the $2\theta_s$ angle selects the desired $|\mathbf{Q}|$:
   $\mathbf{Q} = \mathbf{k}_i - \mathbf{k}_f \longrightarrow |\mathbf{Q}|^2 = |\mathbf{k}_i|^2 + |\mathbf{k}_f|^2 - 2|\mathbf{k}_i||\mathbf{k}_f|\cos(2\theta_s)$

4) Rotation of the sample table, A_3, (single crystals) selects the desired reciprocal lattice coordinates: [H, K, L] = **Q**

5) Multiplexing of analyzers and detectors (such as double bounce in MACS) can greatly increase S(**Q**,E) coverage.

Example: Quantum Spin Liquid

https://www.nature.com/articles/nature11659

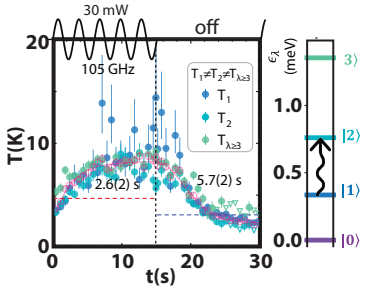


T.-H. Han, et. al. Nature (2012)

Contour plots of the scattering intensity in Q-space (top) show the diffuse patterns resulting from short-range correlation in quantum spin liquid material $ZnCu_3(OD)_6Cl_2$ (herbertsmithite). The contour plots of the scattering intensity as a function of ħω and Q (bottom) show a continuum, a signature of fractional excitations in a quantum spin liquid.

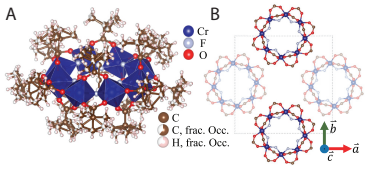
Example: Pumped Molecule Magnet

https://www.pnas.org/doi/10.1073/pnas.2415300121



T.R. Reeder, et. al. PNAS (2025)

Time-dependent temperatures in $Cr_8F_8Piv_{16}$ extracted from the time-resolved inelastic neutron scattering (TRINS) data. A microwave illumination in an applied magnetic field brings two lowest lying states of Cr_8 to resonance, and can be studied by TRINS.



Molecular structure of $Cr_8F_8Piv_{16}$. Cr^{3+} irons form magnetic Cr_8 ring in the ab plane.

Instrument Webpage

Multi-Axis Crystal Spectrometer (MACS)

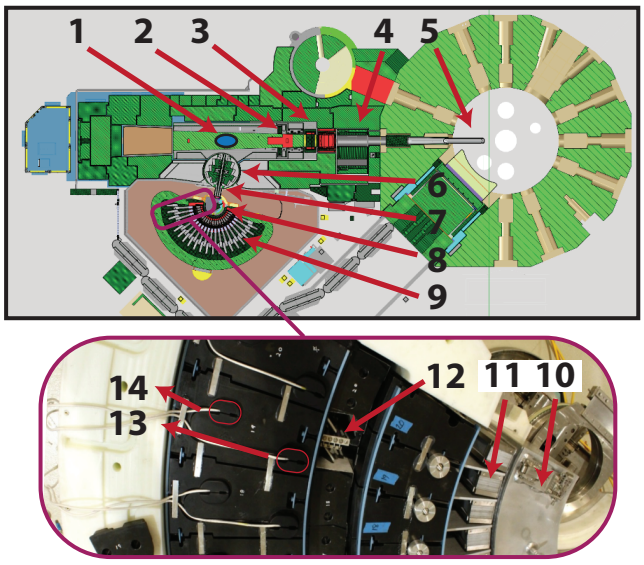
Instrument Paper: https://doi.org/10.1088/0957-0233/19/3/034023

Instrument Webpage: https://www.nist.gov/ncnr/chrns-macs-multi-axis-crystal-spectrometer

CHRNS NSF CENTER FOR HIGH RESOLUTION NEUTRON SCATTERING

NIST CENTER FOR NEUTRON RESEARCH

MACS is a world-leading cold neutron spectrometer that provides the most intense monochromatic cold-neutron beam in the world. The large 20-detector analyzer array allows data collection in a complete energy-plane with only a few instrument settings. Moreover, exceptional polarized beam capabilities over this entire angular range makes MACS well suited for surveys of large regions of reciprocal space, which are invaluable for investigations of low-dimensional magnetic systems, novel superconductors, and related quantum materials.



1) Monochromator
2) Variable Beam Aperture
3) Incident Beam Filters
4) Shutter
5) Cold Source
6) Focusing Mirrors
7) Pre-sample Optics
8) Sample Stage
9) Analyzer System
10) Scattered Beam Filters
11) 90′ Soller Collimators
12) Double-bounce Analyzers
13) Diffraction Detectors
14) Spectroscopic Detectors

Cryostats

System	Range
Dilution Fridge	50 mK - 30 K
^{3}He Dipper	300 mK - 40 K
ILL Orange Cryostat	1.5 K - 300 K
Closed Cycle Fridge (CCR)	2.5 K - 700 K
Cryofurnace	300 K - 1900 K

Magnetic field

(Split Coil, Vertical field)

System	Restrictions
0 - 11 T Magnet	50 mK - 20 K
0 - 4.5 T Magnet	50 mK - 700 K

Electric field

System	Restrictions
±[0.1, 5] kV Power Supply - Current Limiting Switch - 5 mA max current	1.5 K - 600 K and 0 T - 10 T

Pressure

System	Restrictions
Ambient - 2.5 GPa	1.5 K - 300 K (No Field)

Monochromator

- **44 x 36 cm² area:** Comprised of 357 - 2 x 2 cm² squares
- **Double focusing capability:** $2.3 < E_i < 17$ meV
- **PG(002) (60′ mosaic):** $d_{002} = 3.354$ Å

Sample Stage

- **Beam Size:** 2 x 4 cm (Double Focused)
- **Sample Translation:** ±1 cm (X, Y), ±1.5 (Z)
- **Sample Tilt:** ±8° (Sample Env. Dependent)
- **Scattering Angle:** $-140° < 2\theta_s < 140°$ (E_i Dep.)

Analyzer System

- **Multiplexed Array:** 20 detector channels with 8° separation.
- **PG(002) (84′ mosaic):** Vertically focused, double bounce analyzers comprised of 9 - 2 x 6 cm crystals per channel.
- **Detectors:** Diffraction and spectroscopic single detector per channel.
- **Collimation:** Fixed 90′ Soller collimators per channel.

Collimation

Open - M - Open - S - 90′(fixed) - Open - D

Filtration

- **Upstream:**
  - PG Filter
  - Cold Be Filter: $E_i < 5$ meV
- **Downstream:**
  - PG Filter
  - Cold Be Filter: $E_f < 5$ meV
  - Cold BeO Filter: $E_f < 3.7$ meV

Polarization

- ^{3}He polarizers before and after sample
- Polarization Modes: **P⊥Q**

Fluxes

E_i (meV)	n/cm²/s
2.4	6.0×10^7
5	2.0×10^8
10	3.7×10^8