Neutron polarization analysis on multi-detector instruments / XYZ linear polarization analysis

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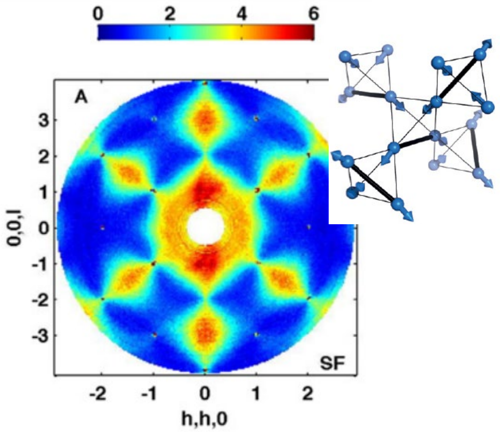
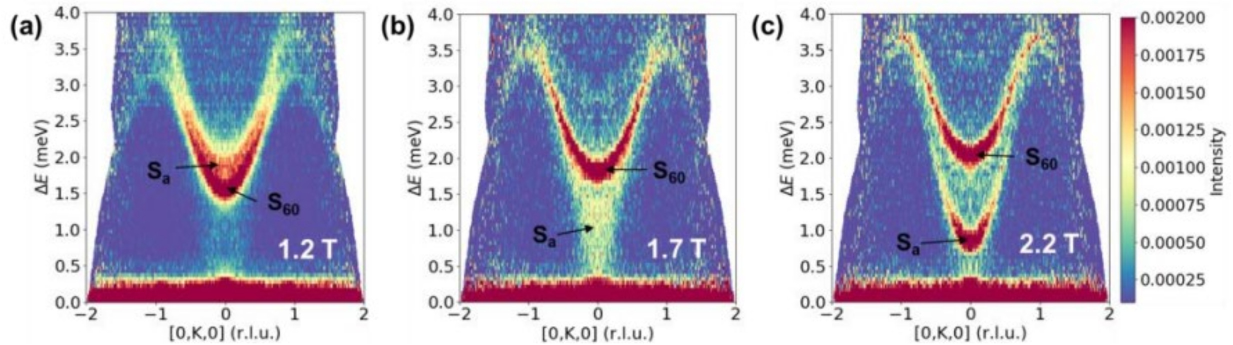
When is wide-angle polarization analysis capability important?

- ❑ magnetic diffuse scattering - large simultaneous Q-coverage (separates magnetic from nuclear scattering)
- ❑ enables polarized INS measurements of a broad range of Q-ω space (separation of magnons and phonons)
- ❑ probes the continuum of fractionalized excitations (broad and isotropic in spin space)
- ❑ study interacting quasiparticles & quantum renormalization of interactions

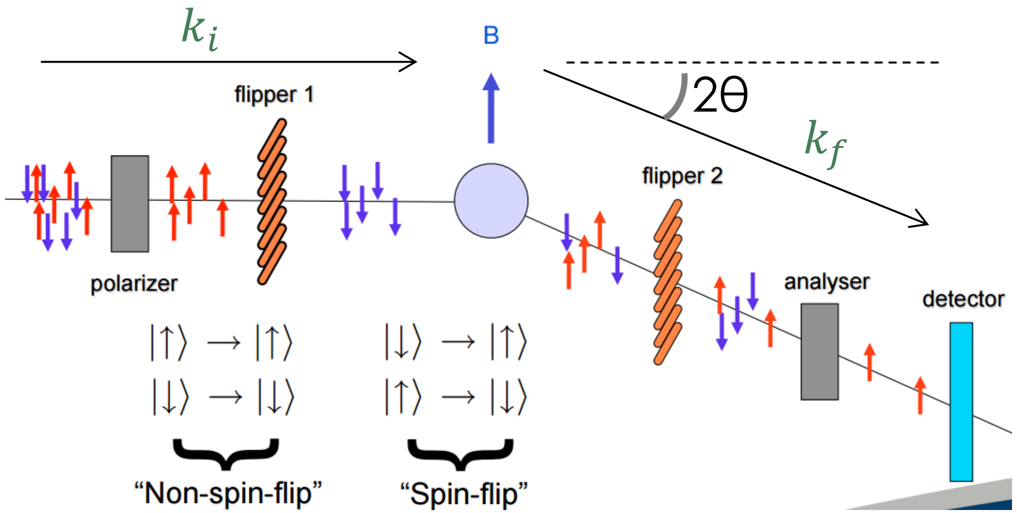


pinch points from
spin-ice state in Ho2Ti2O7
Fennell et al, Science, 326, 415 (2009)



field-induced continua in a Kitaev candidate
Co^{2+} honeycomb layered oxide (*Yuan Li et al.)*

Linear polarization analysis

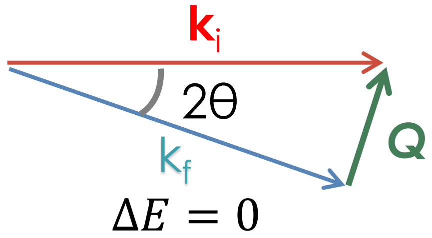


$Q = \overrightarrow{k_i} - \overrightarrow{k_f}$ wavevector transfer

$\Delta E = E_i - E_f = \frac{\hbar^2}{2m}(k_i^2 - k_f^2)$ energy transfer

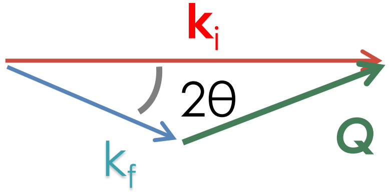
<u>Elastic scattering</u>

$(|k_i| = |k_f| = 2\pi/\lambda)$.



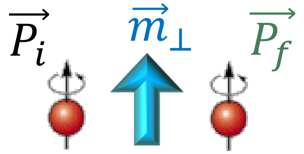
<u>Inelastic scattering</u>

$(|k_i| \neq |k_f|)$



- For single detector there is a well-defined Q direction
- One can easily align P //Q or P⊥Q / to take advantage of $\mathbf{M}_\perp(\mathbf{Q}) = \hat{\mathbf{Q}} \times \mathbf{M}(\mathbf{Q}) \times \hat{(\mathbf{Q})}$

Non Spin Flip (NSF)

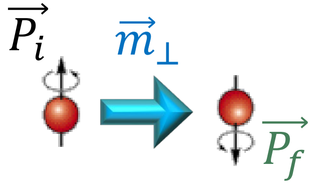


P || Q

NSF : $I_{xx} = N^*N + {}^1/_3\, I_{SI}$

SF: $I_{\bar{x}x} = M_\perp M_\perp^* \pm \mathrm{i}\, P(\overrightarrow{M}_\perp \times \overrightarrow{M}_\perp^*) + {}^2/_3\, I_{SI}$

Spin Flip (SF)



P⊥Q

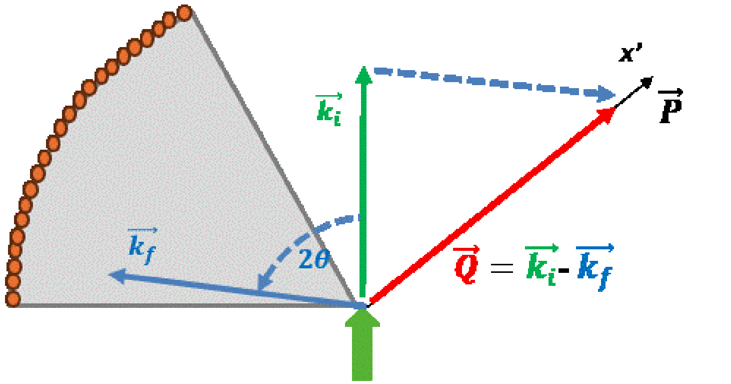
NSF : $I_{zz} = N^*N + M_{\perp z}M_{\perp z}^* \pm P(NM_{\perp z}^* + N^*M_{\perp z}) + {}^1/_3\, I_{SI}$

SF: $I_{\bar{z}z} = M_{\perp y}M_{\perp y}^* + {}^2/_3\, I_{SI}$

Linear polarization analysis in wide-angle detectors

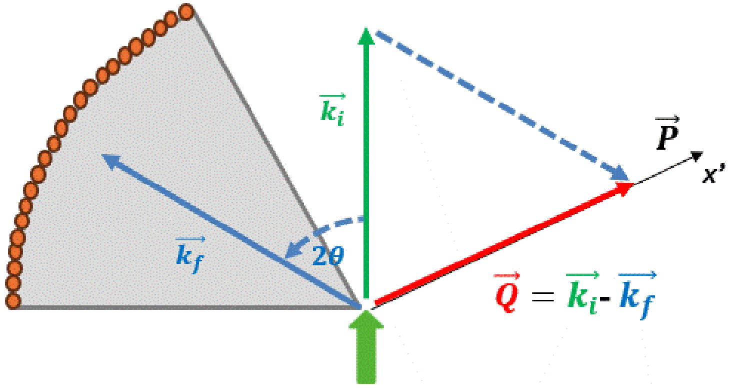
- direction of **Q** with respect to **P** varies significantly as a function of the detector position and energy transfer

the same energy but different detector positions:



P II Q, P⊥ Q for what detector and what energy transfer ?

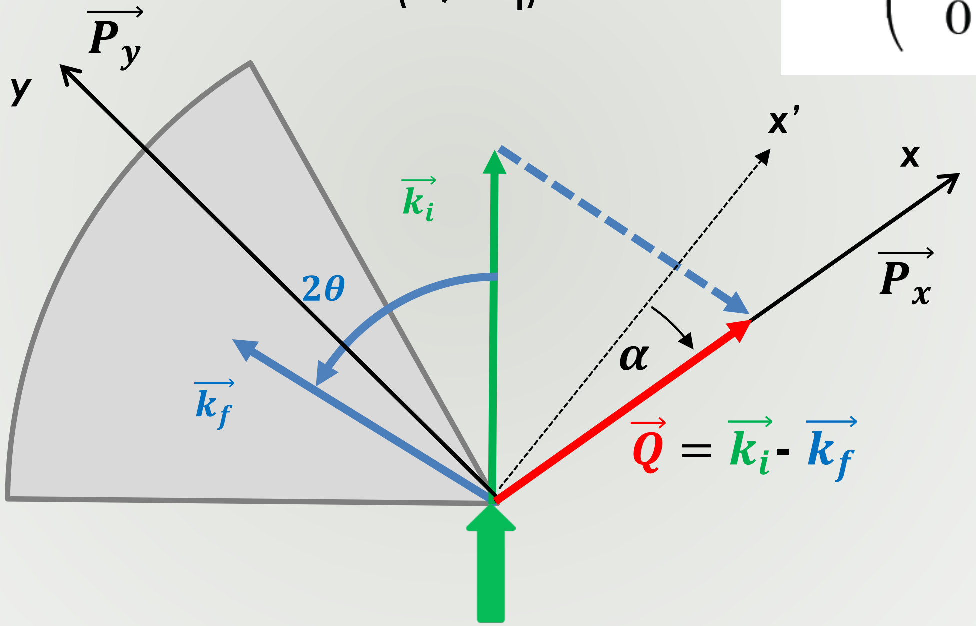
the same detector but different energies:



--> set XYZ coordinate system defined by a fixed polarization direction.

$$\hat{\mathbf{Q}} = \begin{pmatrix} \cos\alpha \\ \sin\alpha \\ 0 \end{pmatrix}$$

∝ = ∠ (**P**, **Q**$_\mathbf{i}$)



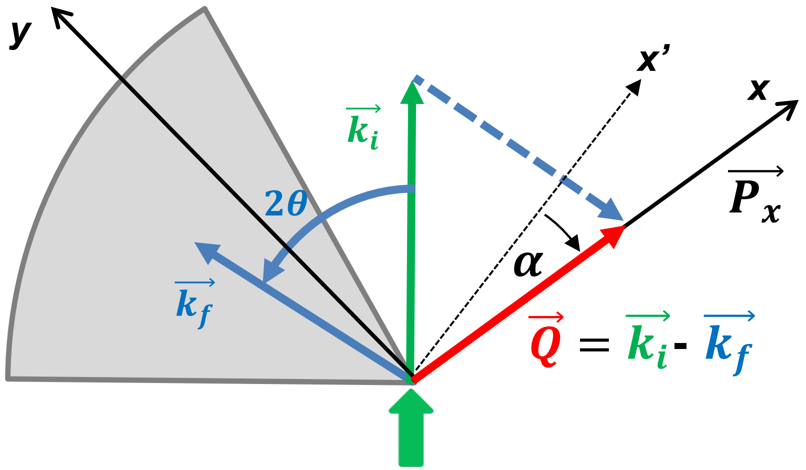
Linear polarization analysis in wide-angle detectors

Schärpf and Capellmann, Phys. Stat. Sol. 135 (1993)

The *XYZ*-Difference Method with Polarized Neutrons and the Separation of Coherent, Spin Incoherent, and Magnetic Scattering Cross Sections in a Multidetector

"**6-pt method**" (3 orthogonal fields XYZ- SF/NSF)

$$\hat{\mathbf{Q}} = \begin{pmatrix} \cos\alpha \\ \sin\alpha \\ 0 \end{pmatrix}$$



X

$$\left(\frac{d\sigma}{d\Omega}\right)_X^{NSF} = \frac{1}{2}\sin^2\alpha\left(\frac{d\sigma}{d\Omega}\right)_{mag} + \frac{1}{3}\left(\frac{d\sigma}{d\Omega}\right)_{SI} + \left(\frac{d\sigma}{d\Omega}\right)_{nuc+II}$$

$$\left(\frac{d\sigma}{d\Omega}\right)_X^{SF} = \frac{1}{2}(\cos^2\alpha + 1)\left(\frac{d\sigma}{d\Omega}\right)_{mag} + \frac{2}{3}\left(\frac{d\sigma}{d\Omega}\right)_{SI}$$

Y

$$\left(\frac{d\sigma}{d\Omega}\right)_Y^{NSF} = \frac{1}{2}\cos^2\alpha\left(\frac{d\sigma}{d\Omega}\right)_{mag} + \frac{1}{3}\left(\frac{d\sigma}{d\Omega}\right)_{SI} + \left(\frac{d\sigma}{d\Omega}\right)_{nuc+II}$$

$$\left(\frac{d\sigma}{d\Omega}\right)_Y^{SF} = \frac{1}{2}(\sin^2\alpha + 1)\left(\frac{d\sigma}{d\Omega}\right)_{mag} + \frac{2}{3}\left(\frac{d\sigma}{d\Omega}\right)_{SI}$$

Z

$$\left(\frac{d\sigma}{d\Omega}\right)_Z^{NSF} = \frac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)_{mag} + \frac{1}{3}\left(\frac{d\sigma}{d\Omega}\right)_{SI} + \left(\frac{d\sigma}{d\Omega}\right)_{nuc+II}$$

$$\left(\frac{d\sigma}{d\Omega}\right)_Z^{SF} = \frac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)_{mag} + \frac{2}{3}\left(\frac{d\sigma}{d\Omega}\right)_{SI}$$

! Only applicable to Isotropic magnetic scattering (diffuse /powder scattering)

$$\left(\frac{d\sigma}{d\Omega}\right)_{mag} = 2\left[\left(\frac{d\sigma}{d\Omega}\right)_{SF}^{X} + \left(\frac{d\sigma}{d\Omega}\right)_{SF}^{Y} - 2\left(\frac{d\sigma}{d\Omega}\right)_{SF}^{Z}\right]$$

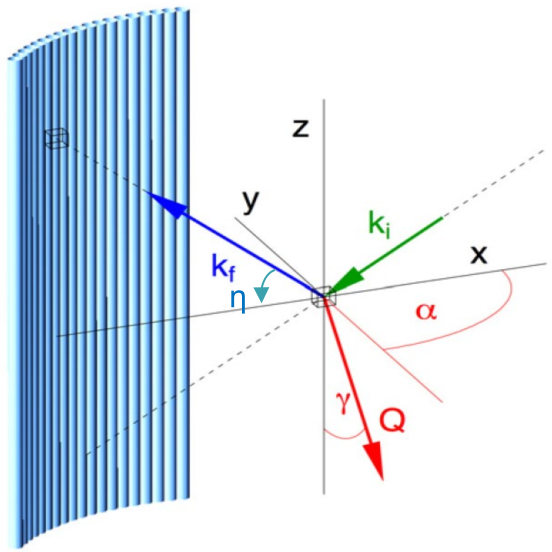
$$\left(\frac{d\sigma}{d\Omega}\right)_{nuc+II} = \frac{1}{6}\left[2\left(\frac{d\sigma}{d\Omega}\right)_{TNSF} - \left(\frac{d\sigma}{d\Omega}\right)_{TSF}\right]$$

$$\left(\frac{d\sigma}{d\Omega}\right)_{SI} = \frac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)_{TSF} - \left(\frac{d\sigma}{d\Omega}\right)_{mag}$$

Linear polarization analysis in wide-angle detectors

- Generalization of the classical *XYZ*-polarization analysis technique to out-of-plane and inelastic scattering

G. Ehlers, R. Stewart, A. R. Wildes, P. P. Deen, K. H. Andersen , Rev. Sci. Instr. 84, 093901 (2013)



$$\frac{\partial\sigma}{\partial\Omega_\downarrow}^{(x)} = \frac{2}{3}\cdot I + \frac{1}{2}\cdot M\cdot(1+\sin^2\gamma\cdot\cos^2\alpha),$$

$$\frac{\partial\sigma}{\partial\Omega_\uparrow}^{(x)} = N + \frac{1}{3}\cdot I + \frac{1}{2}\cdot M\cdot(1-\sin^2\gamma\cdot\cos^2\alpha),$$

$$\frac{\partial\sigma}{\partial\Omega_\downarrow}^{(y)} = \frac{2}{3}\cdot I + \frac{1}{2}\cdot M\cdot(1+\sin^2\gamma\cdot\cos^2(\alpha-\pi/2)),$$

$$\frac{\partial\sigma}{\partial\Omega_\uparrow}^{(y)} = N + \frac{1}{3}\cdot I + \frac{1}{2}\cdot M \cdot(1-\sin^2\gamma\cdot\cos^2(\alpha-\pi/2)),$$

$$\frac{\partial\sigma}{\partial\Omega_\downarrow}^{(z)} = \frac{2}{3}\cdot I + \frac{1}{2}\cdot M\cdot(1+\cos^2\gamma),$$

$$\frac{\partial\sigma}{\partial\Omega_\uparrow}^{(z)} = N + \frac{1}{3}\cdot I + \frac{1}{2}\cdot M\cdot(1-\cos^2\gamma),$$

$$\tilde{Q} = [\cos\alpha\sin\gamma, \sin\alpha\sin\gamma, \cos\gamma].$$

Isotropic magnetic scattering:

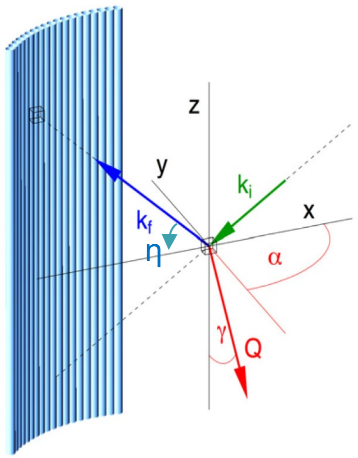
$$\frac{M}{2}\cdot(1-3\cos^2\gamma) = \frac{\partial\sigma}{\partial\Omega_\downarrow}^{(x)} + \frac{\partial\sigma}{\partial\Omega_\downarrow}^{(y)} - 2\cdot\frac{\partial\sigma}{\partial\Omega_\downarrow}^{(z)}$$

$$6\cdot N = 2\cdot\left(\frac{\partial\sigma}{\partial\Omega_\uparrow}^{(x)} + \frac{\partial\sigma}{\partial\Omega_\uparrow}^{(y)} + \frac{\partial\sigma}{\partial\Omega_\uparrow}^{(z)}\right) - \left(\frac{\partial\sigma}{\partial\Omega_\downarrow}^{(x)} + \frac{\partial\sigma}{\partial\Omega_\downarrow}^{(y)} + \frac{\partial\sigma}{\partial\Omega_\downarrow}^{(z)}\right)$$

$$N + I + M = \frac{1}{3}\cdot\left(\frac{\partial\sigma}{\partial\Omega_\downarrow}^{(x)} + \frac{\partial\sigma}{\partial\Omega_\uparrow}^{(x)} + \frac{\partial\sigma}{\partial\Omega_\downarrow}^{(y)} + \frac{\partial\sigma}{\partial\Omega_\uparrow}^{(y)} + \frac{\partial\sigma}{\partial\Omega_\downarrow}^{(z)} + \frac{\partial\sigma}{\partial\Omega_\uparrow}^{(z)}\right)$$

The mixture of M and I (Nuclear Spin Incoh.) depends on γ angle

Linear polarization analysis in wide-angle detectors



- The correction for the out-of-plane γ angle requires additional measurements with ***P*** parallel to the x + y and x − y directions

Ehlers et al. Rev. Sci. Instr. 84, 093901 (2013)

"10-pt method"

$$\frac{\partial\sigma}{\partial\Omega_{\downarrow}}^{(x+y)} = \frac{2}{3}\cdot I + \frac{1}{2}\cdot M\cdot(1+\sin^2\gamma\cdot\cos^2(\alpha-\pi/4)),$$

$$\frac{\partial\sigma}{\partial\Omega_{\uparrow}}^{(x+y)} = N + \frac{1}{3}\cdot I + \frac{1}{2}\cdot M\cdot(1-\sin^2\gamma\cdot\cos^2(\alpha-\pi/4)),$$

$$\frac{\partial\sigma}{\partial\Omega_{\downarrow}}^{(x-y)} = \frac{2}{3}\cdot I + \frac{1}{2}\cdot M\cdot(1+\sin^2\gamma\cdot\cos^2(\alpha+\pi/4)),$$

$$\frac{\partial\sigma}{\partial\Omega_{\uparrow}}^{(x-y)} = N + \frac{1}{3}\cdot I + \frac{1}{2}\cdot M\cdot(1-\sin^2\gamma\cdot\cos^2(\alpha+\pi/4)),$$

Isotropic magnetic scattering:

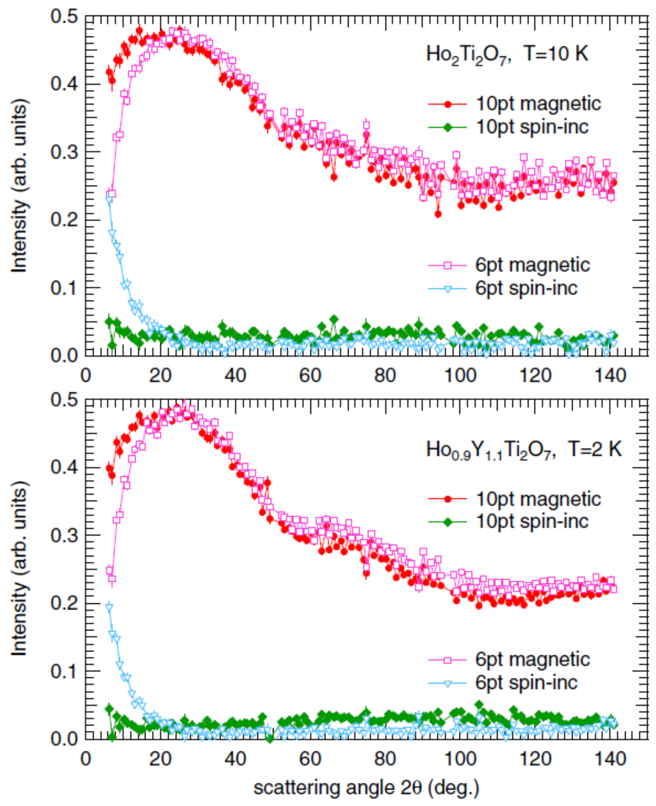
$$\frac{1}{2}\cdot M\cdot\sin^2\gamma = \pm\left\{\left(\frac{\partial\sigma}{\partial\Omega_{\downarrow}}^{(x)} - \frac{\partial\sigma}{\partial\Omega_{\downarrow}}^{(y)}\right)^2 + \left(\frac{\partial\sigma}{\partial\Omega_{\downarrow}}^{(x+y)} - \frac{\partial\sigma}{\partial\Omega_{\downarrow}}^{(x-y)}\right)^2\right\}^{1/2}$$

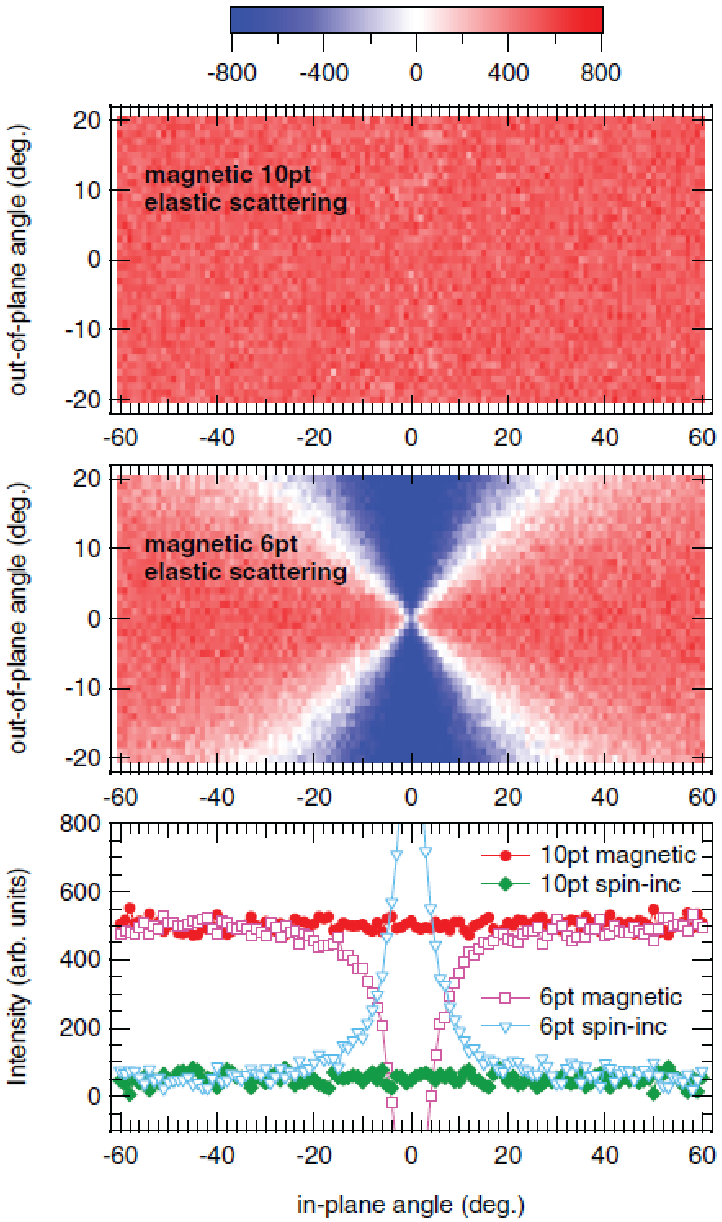
$$\frac{M}{2}\cdot(1-3\cos^2\gamma) = \frac{\partial\sigma}{\partial\Omega_{\downarrow}}^{(x)} + \frac{\partial\sigma}{\partial\Omega_{\downarrow}}^{(y)} - 2\cdot\frac{\partial\sigma}{\partial\Omega_{\downarrow}}^{(z)}$$

Linear polarization analysis in wide-angle detectors

Ehlers et al. Rev. Sci. Instr. 84, 093901 (2013)

Separating diffuse magnetic scattering from the nuclear spin incoherent scattering for He2Ti2O7 powder, D7 (ILL) data, γ +/- 5 deg

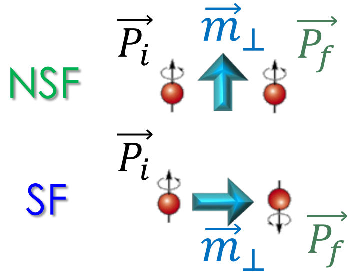




Simulation for:
$M(Q)$ = const.
$I(Q)$ = const.
$M : I = 10 : 1$

More general equation for single crystals anisotropic scattering

W. Schweika, J. Physics: Conf. Series 211, 012026 (2010) "6-pt method" : $\upsilon = x, y, z$

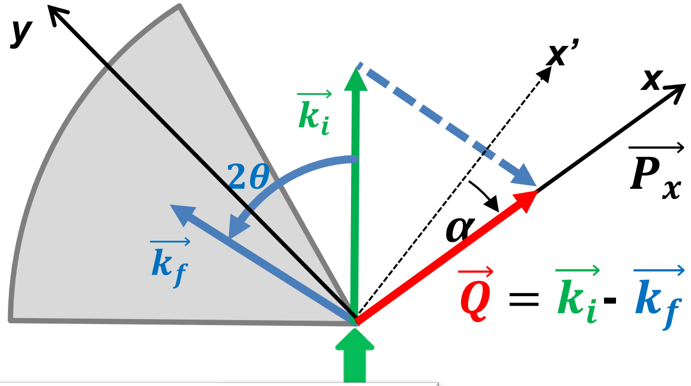


$m_\perp$|| P

$$I_{\nu\nu} = N^*N + M_{\perp\nu}M^*_{\perp\nu} + \vec{P}(NM^*_{\perp\nu} + N^*M_{\perp\nu}) + {}^1/_3\, I_{SI}$$

$$I_{\bar{\nu}\nu} = \vec{M}_\perp \vec{M}^*_\perp - M_{\perp\nu}M^*_{\perp\nu} - \vec{P}\,(\vec{M}_\perp \times \vec{M}^*_\perp) \quad + {}^2/_3\, I_{SI}$$

$m_\perp \perp$ P



$$\Sigma^{nsf}_\nu = \frac{1}{2}(I_{\nu\nu} + I_{\bar{\nu}\bar{\nu}}) = N^\dagger N + M^\dagger_{\perp\nu}M_{\perp\nu} + \frac{1}{3}I_{si}$$

$$\Sigma^{sf}_\nu = \frac{1}{2}(I_{\nu\bar{\nu}} + I_{\bar{\nu}\nu}) = \mathbf{M}^\dagger_\perp \mathbf{M}_\perp - M^\dagger_{\perp\nu}M_{\perp\nu} + \frac{2}{3}I_{si}$$

$$\Delta^{nsf}_\nu = \frac{1}{2}(I_{\nu\nu} - I_{\bar{\nu}\bar{\nu}}) = NM^\dagger_{\perp\nu} + N^\dagger M_{\perp\nu} = 2\Re(NM^\dagger_{\perp\nu})$$

$$\Delta^{sf}_\nu = \frac{1}{2}(I_{\nu\bar{\nu}} - I_{\bar{\nu}\nu}) = 2\mathrm{i}(\mathbf{M}^\dagger_\perp \times \mathbf{M}_\perp)_\nu \,.$$

$$N^\dagger N = \frac{1}{2}\left(\Sigma^{nsf}_x + \Sigma^{nsf}_y - \Sigma^{sf}_z\right) = \frac{1}{2}(\Sigma^{nsf}_{x'} + \Sigma^{nsf}_{y'} - \Sigma^{sf}_z)$$

$$I_{si} = \frac{3}{2}(\Sigma^{nsf}_x - \Sigma^{nsf}_y + \Sigma^{sf}_z) = \frac{3}{2}\frac{\Sigma^{nsf}_{x'} - \Sigma^{nsf}_{y'}}{\cos^2\alpha - \sin^2\alpha} + \frac{3}{2}\Sigma^{sf}_z$$

$$M^\dagger_{\perp y}M_{\perp y} = \Sigma^{sf}_z - \frac{2}{3}I_{si}$$

$$M^\dagger_{\perp z}M_{\perp z} = \Sigma^{nsf}_z - \frac{1}{3}I_{si} - N^\dagger N$$

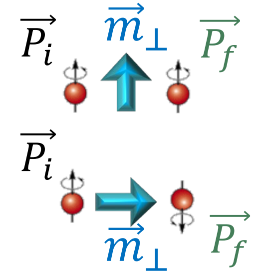
- Note the singularity at α = π/4; The polarization orientation must be chosen to avoid it.

Linear polarization analysis in wide-angle detectors

"6-pt method" : $\nu = x, y, z$

NSF

SF

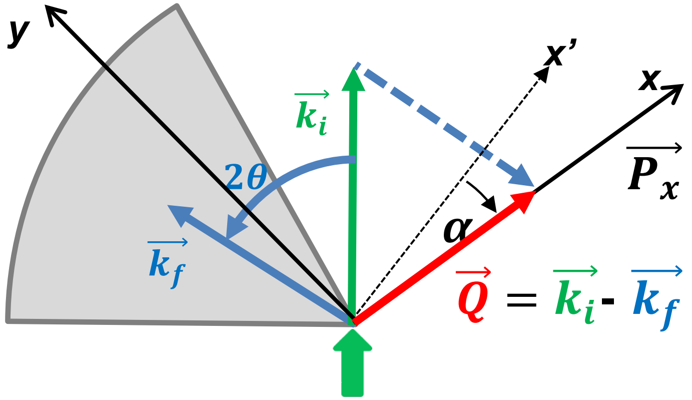


$m_\perp$ || P

$$I_{\nu\nu} = N^*N + M_{\perp\nu}M^*_{\perp\nu} + \vec{P}(NM^*_{\perp\nu} + N^*M_{\perp\nu}) + {}^1/_3\, I_{SI}$$

$$I_{\bar{\nu}\nu} = \vec{M}_\perp \vec{M}^*_\perp - M_{\perp\nu}M^*_{\perp\nu} - \vec{P}\,(\vec{M}_\perp \times \vec{M}^*_\perp) \quad + {}^2/_3\, I_{SI}$$

$m_\perp \perp$ P



No flipping of the scattered neutrons (no wide-angle flipper) → only $I_{\nu\nu}$ and $I_{\bar{\nu}\nu}$ can be obtained

Half - Polarized Neutron Scattering

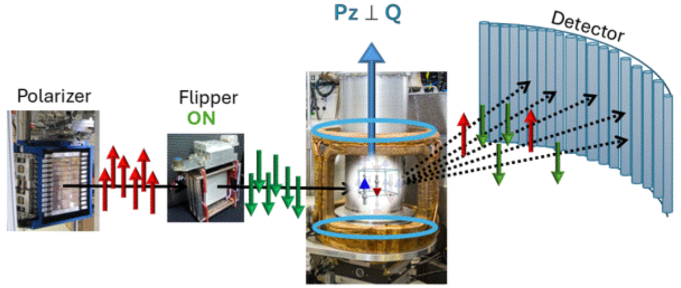
$$I_{\nu 0} = I_{\nu\nu} + I_{\nu\bar{\nu}}$$
$$I_{\bar{\nu}0} = I_{\bar{\nu}\nu} + I_{\bar{\nu}\bar{\nu}}$$

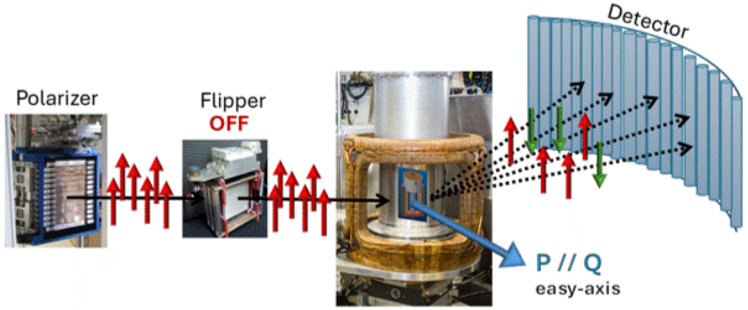
$\vec{P} \,//\, z\,, y \perp \mathbf{Q}$

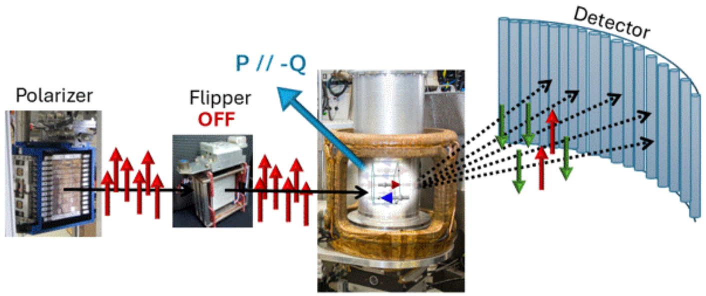
$$I_{z0} - I_{\bar{z}0} = 2P(NM^*_{\perp z} + N^*M_{\perp z})$$

$\vec{P} \,//\, x \,//\, \mathbf{Q}$

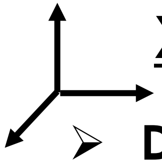
$$I_{x0} - I_{\bar{x}0} = M_{\perp z}M^*_{\perp y} - M_{\perp y}M^*_{\perp z}$$



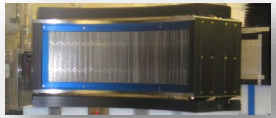




Multi-detector instruments with polarization analysis capability



XYZ Polarization analysis



- **D7 (ILL)** – diffuse scattering
  – Cold neutrons, supermirror benders (145 °)
  – t-o-f with ~ 4% ΔE/Ei resolution

- **DNS (FRM-2)** – diffuse scattering

- **HYSPEC (SNS)** – hybrid t-o-f
  – Cold neutrons, Heusler polarizer and 60° supermirror bender (E_f<30meV)
  – Hybrid t-o-f with energy resolution 3-5% E_i

- **POLANO (J-PARC)** - t-o-f
  – SEOP ^{3}He gas spin filter and 40° bending mirror analyzer, (E_f<40meV)

↑ Z - only Polarization analysis

- **MACS (NIST)** – multiplex TAS
  – Cold neutrons, compact ^{3}He polarizer and wide-angle analyzer cell
  – Large energy resolution range

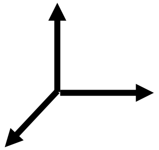
- **LET (ISIS)** – t-o-f
  – Cold neutrons,
  – V-cavity and wide-angle ^{3}He,
  – Large energy resolution range and choice

- **PELICAN (ANSTO)** – t-o-f
  supermirror polarizer and ^{3}He filter analyzer
  – energy resolution ~2.5% of E_i

- **CNCS (SNS)** – t-o-f (^{3}He polarizer and analyzer)

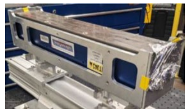
supermirror analyzer:
- 👍 Stable configuration
- 👍 Low-maintenance
- 👍 Easy to implement XYZ analysis
- 👎 Expensive

Multi-detector instruments with polarization analysis capability

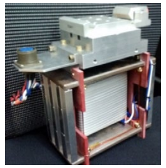


XYZ Polarization analysis

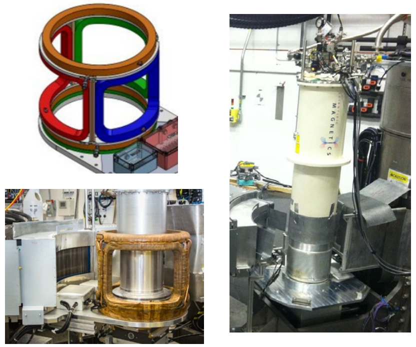
Polarizers



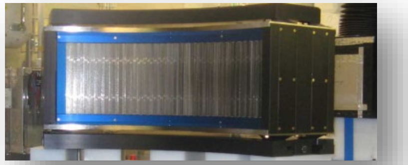
Flipper



Guide fields

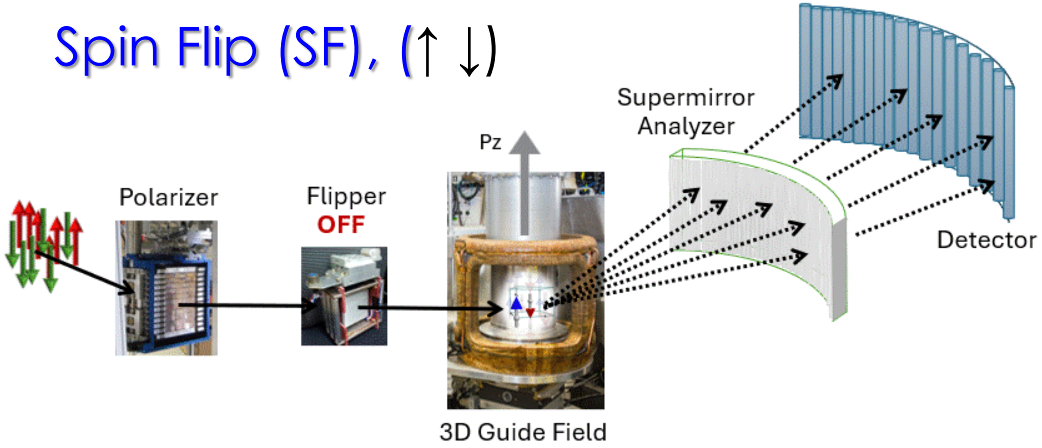


Analyzer filter

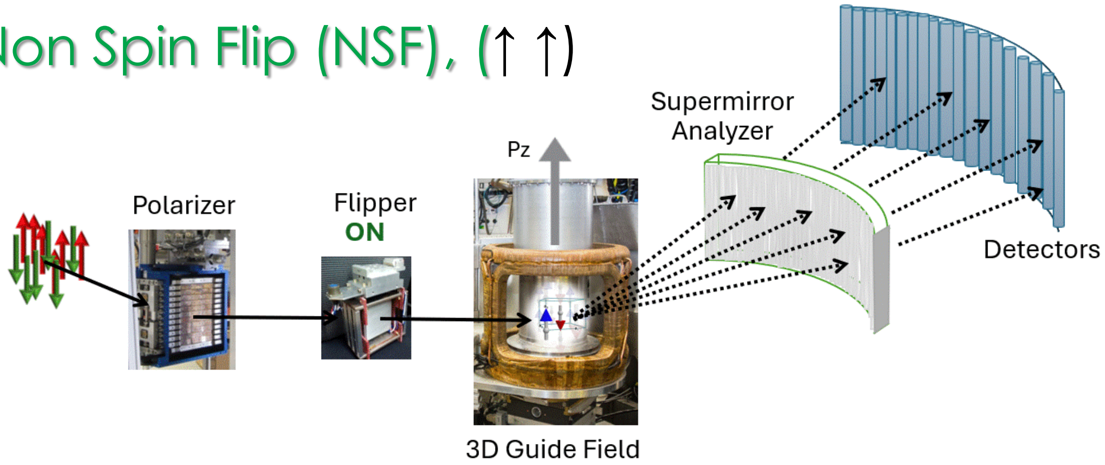


"**6-pt method**" (P_X, P_Y, P_Z - SF/NSF)

Spin Flip (SF), (↑ ↓)



Non Spin Flip (NSF), (↑ ↑)

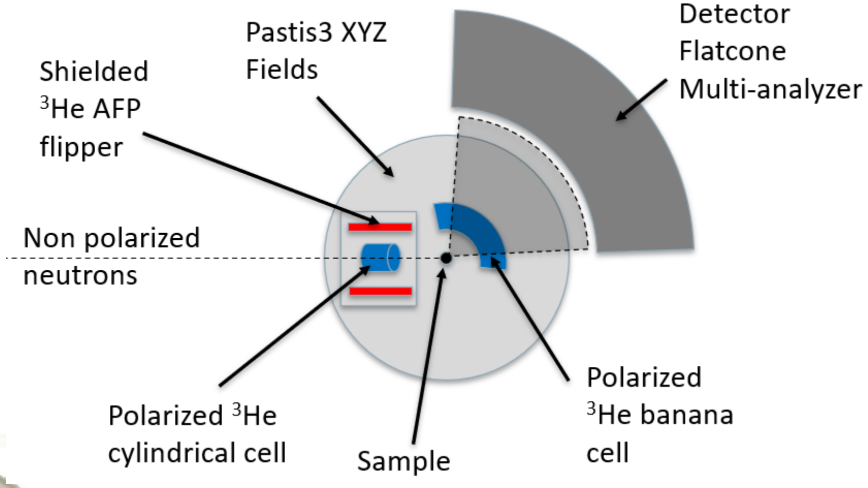


Multi-detector instruments with polarization analysis capability

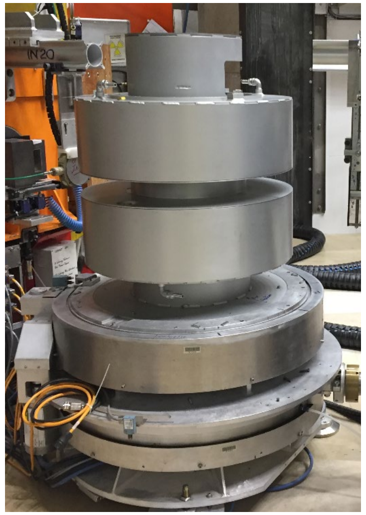
XYZ Polarization Analysis on Thermal Inelastic Spectrometers (PASTIS)

❑ PASTIS-3 for IN20 thermal triple axis at the ILL

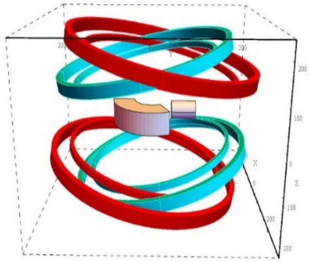
- ❖ Include ^{3}He polarizer, analyzer, and ^{3}He AFP (Adiabatic Fast Passage) Flipper
- ❖ Free access 130° in the horizontal plane, 12° in the vertical plane
- ❖ Wavelength range starting from 1Å
- ❖ Field homogeneity for an overall cells relaxation time T_1 > 100h



PASTIS-3



Banana type analyzer cells with Si-windows



2 pairs of compensated Helmholtz coils, tilted to produce guide-field in the YZ plane

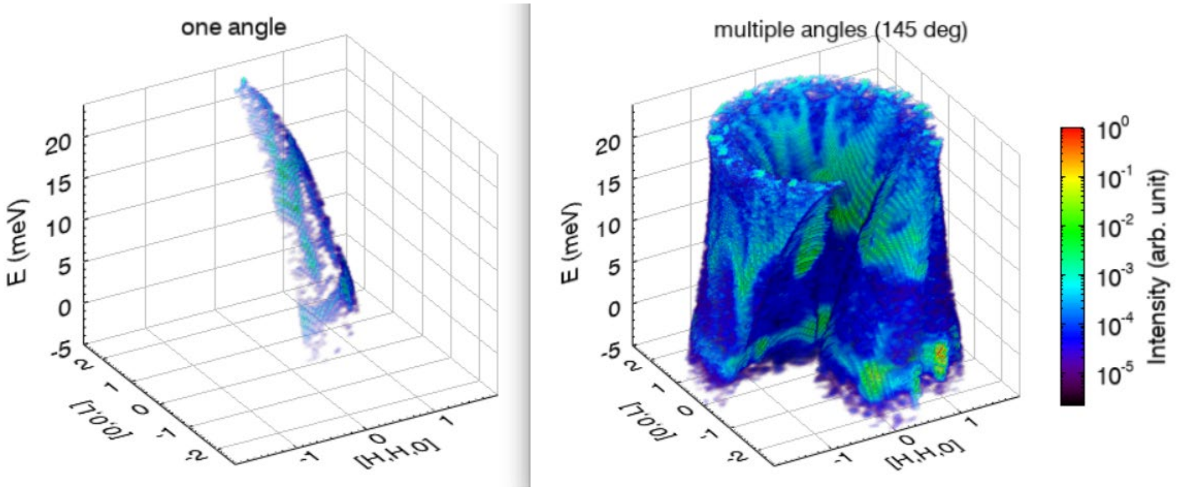
D. Jullien, A. Petoukhov, M. Enderle, N. Thiery, P. Mouveau, U.B. Hansen, P. Chevalier, & P. Courtois. *NIM A*, *1010*, 165558 (2021).

❑ Prototype under development for PANTHER thermal TOF spectrometer

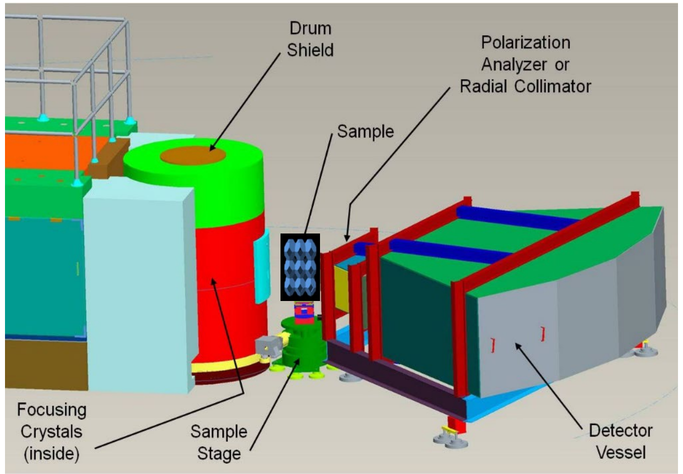
Typical measurements using single-crystals at HYSPEC

Sample pre-aligned in a specific HKL scattering plane
and is rotated around vertical direction ("omega" angle)

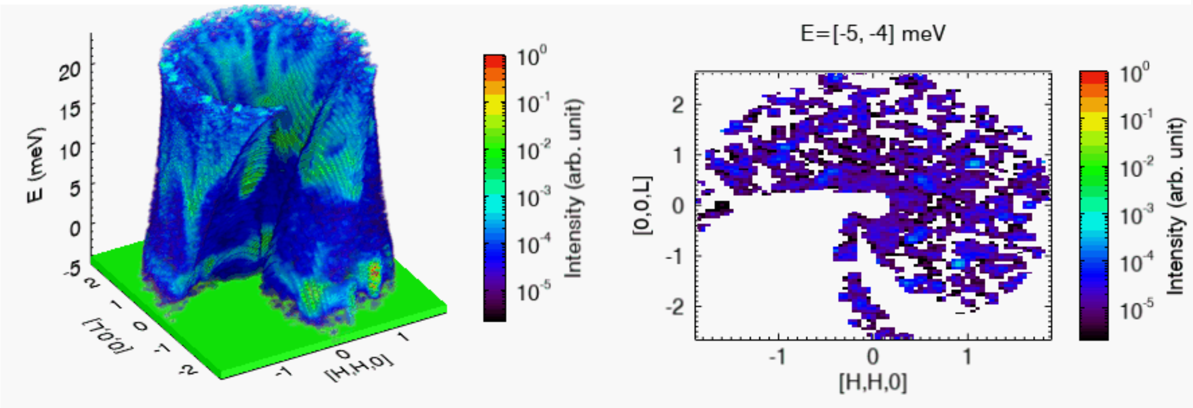
$\Delta E = E_i - E_f$



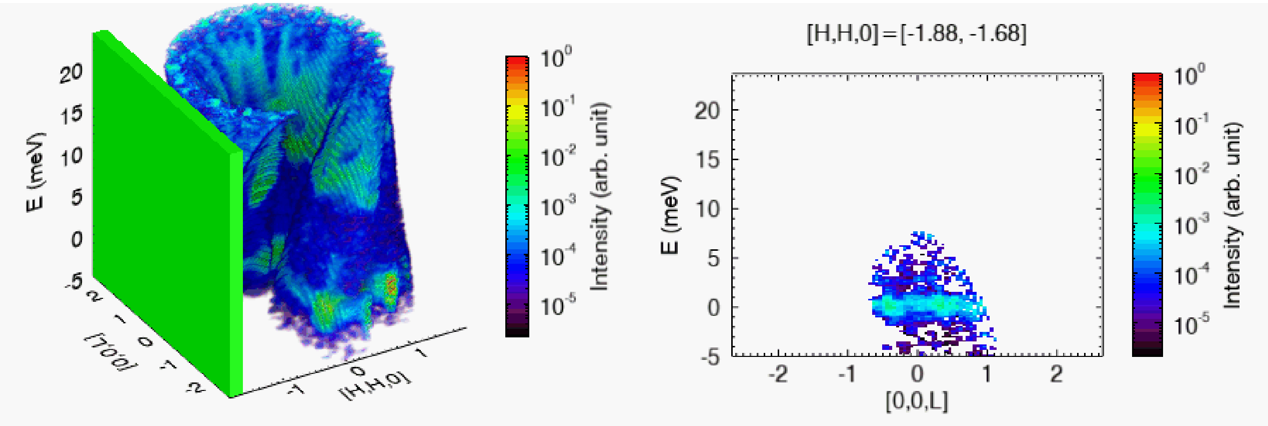
HYSPEC detector bank :
60° (Horiz), +/- 7 ° (Vert)



Q slices for various energy transfer ΔE=1meV

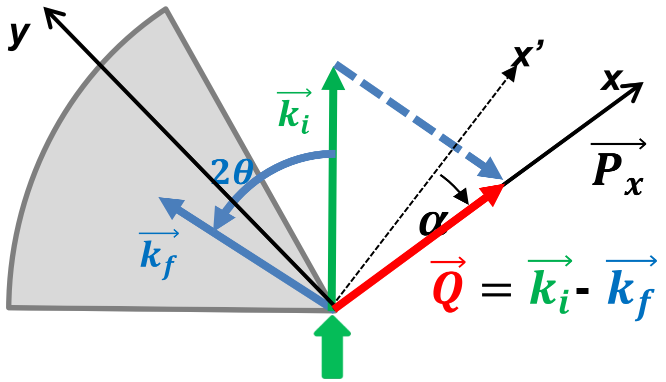


Q-L slices for various HH positions



Linear polarization analysis using HYSPEC

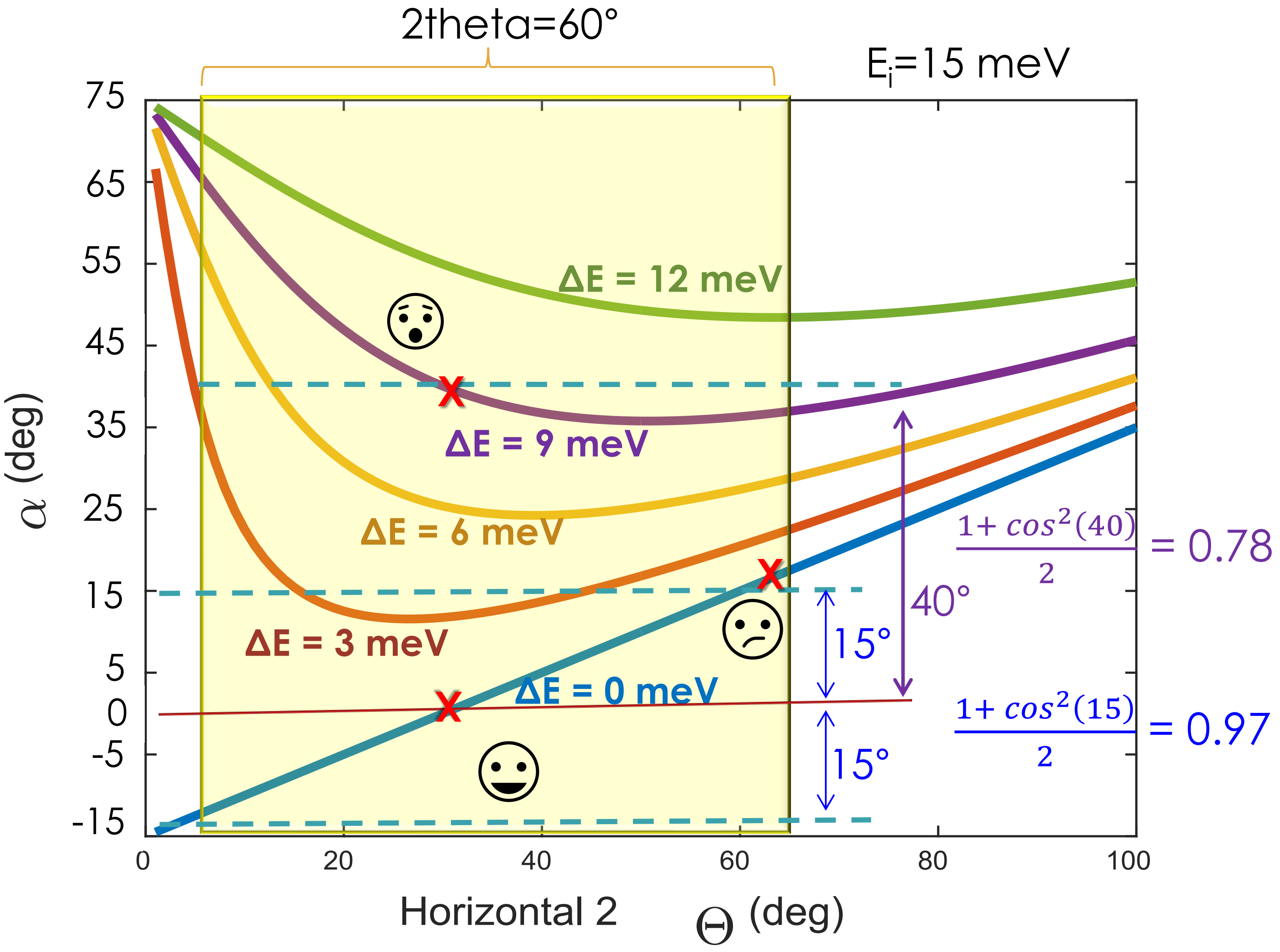
HYSPEC detector bank : 60°
(positioned to cover 2Θ = 3 ° -105 °)



Dependence on alpha of magnetic scattering:

$$\left(\frac{d\sigma}{d\Omega}\right)_X^{SF} = \frac{1}{2}\left(\cos^2\alpha + 1\right)\left(\frac{d\sigma}{d\Omega}\right)_{mag} + \frac{2}{3}\left(\frac{d\sigma}{d\Omega}\right)_{SI}$$

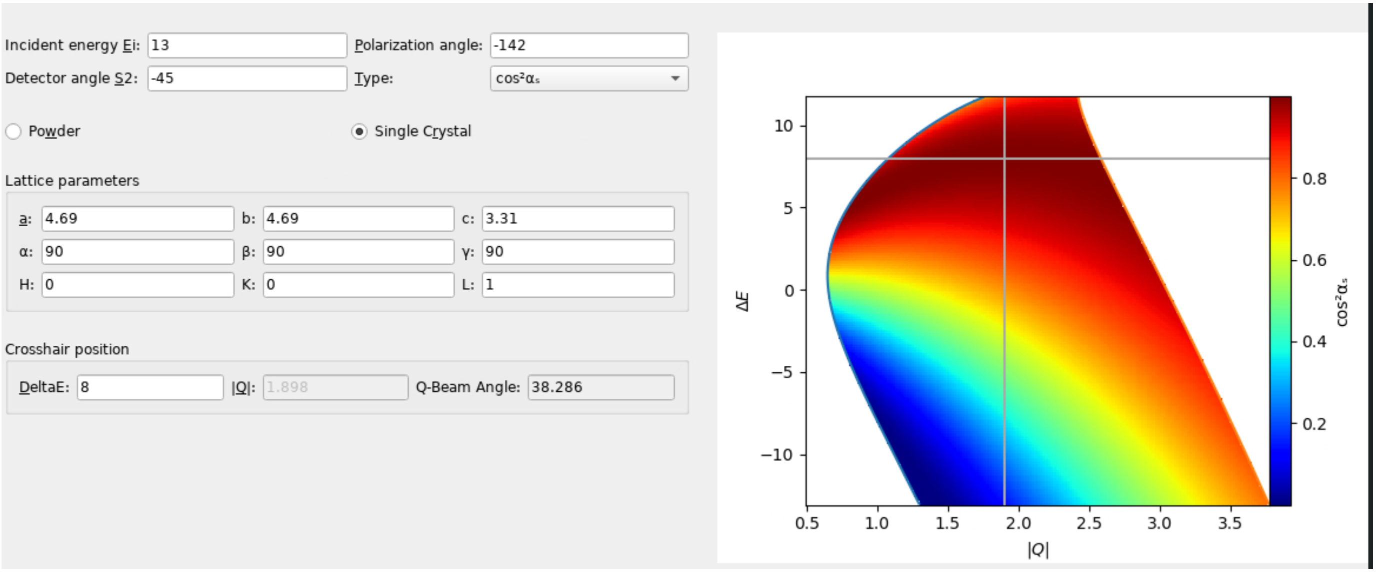
$$\left(\frac{d\sigma}{d\Omega}\right)_Y^{SF} = \frac{1}{2}\left(\sin^2\alpha + 1\right)\left(\frac{d\sigma}{d\Omega}\right)_{mag} + \frac{2}{3}\left(\frac{d\sigma}{d\Omega}\right)_{SI}$$



Linear polarization analysis using HYSPEC

$$\left(\frac{d\sigma}{d\Omega}\right)_X^{SF} = \frac{1}{2}\left(\cos^2\alpha + 1\right)\left(\frac{d\sigma}{d\Omega}\right)_{mag} + \frac{2}{3}\left(\frac{d\sigma}{d\Omega}\right)_{SI}$$

Optimized P_X //Q : HYSPEC polarization planning tool (Andrei Savici & Kyle Ma)



<u>Strategies at HYSPEC</u>:

i. measure all XYZ (typically, $\mathbf{P_x}$ // $\mathbf{Q_0}$ where $\boldsymbol{k_f}$ is pointing to the middle of detector at the ΔE of interest)

ii. Measure only $\mathbf{P_x}$ (for specific **Q** and ΔE of interest) when the goal is simply to separate magnetic and nuclear scattering

iii. Measure only $\mathbf{P_z}$ (no "**alpha**" correction)

- **P_z_SF :** gives only in-plane magnetic scattering
- **P_z_NSF :** out-of-plane magnetic contribution plus nuclear scattering (subtracting the high temperature data may be needed)

HYSPEC: XYZ-polarization analysis on powder

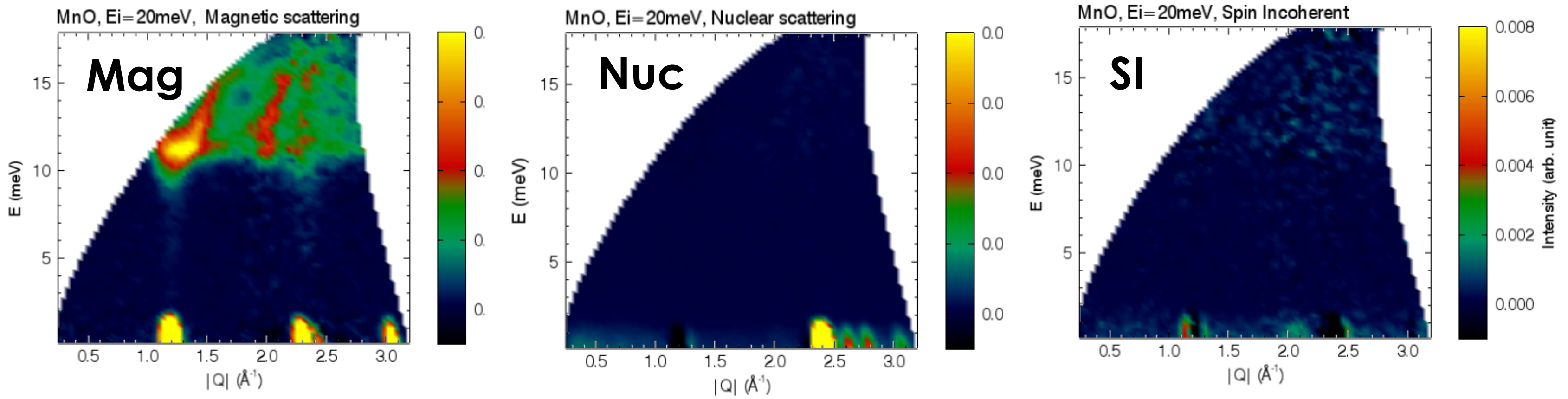
MnO powder, T_N ~ 120K

$$\left(\frac{d\sigma}{d\Omega}\right)_{mag} = 2\left[\left(\frac{d\sigma}{d\Omega}\right)_{SF}^{X} + \left(\frac{d\sigma}{d\Omega}\right)_{SF}^{Y} - 2\left(\frac{d\sigma}{d\Omega}\right)_{SF}^{Z}\right]$$

"6-pt method"

$$\left(\frac{d\sigma}{d\Omega}\right)_{nuc+II} = \frac{1}{6}\left[2\left(\frac{d\sigma}{d\Omega}\right)_{TNSF} - \left(\frac{d\sigma}{d\Omega}\right)_{TSF}\right] \qquad \left(\frac{d\sigma}{d\Omega}\right)_{SI} = \frac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)_{TSF} - \left(\frac{d\sigma}{d\Omega}\right)_{mag}$$

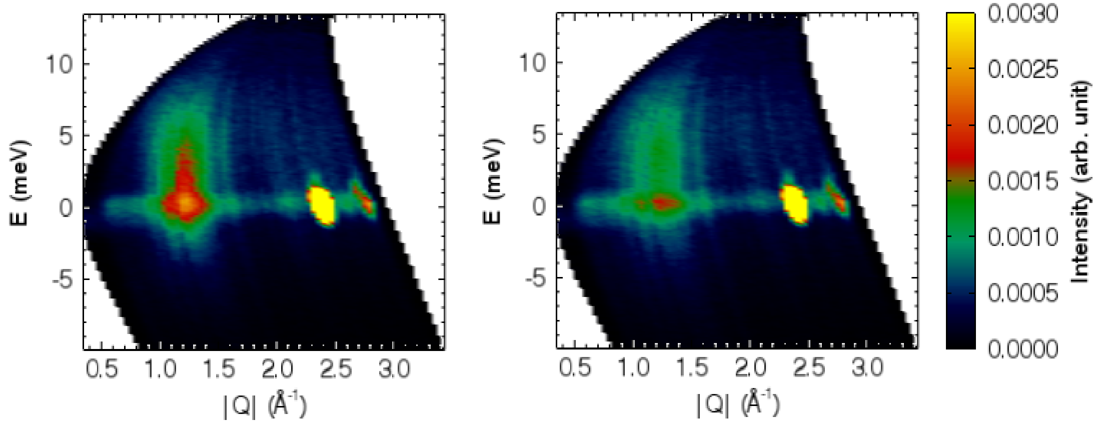
T = 5 K, XYZ →
Ei = 20 meV,



Temp depnd.
Px →
Ei = 15 meV,

SF 150K

SF 250K



HYSPEC: XYZ-polarization analysis on single-crystal

Polarized neutron scattering was used to isolate the diffuse magnetic scattering from nuclear scattering in paramagnetic state of MnO

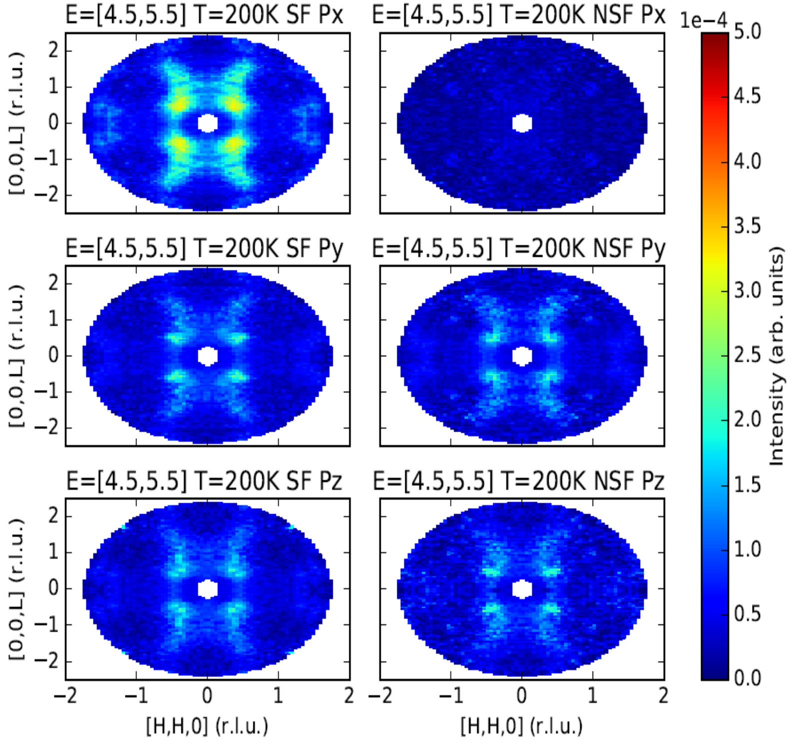
Ei = 25 meV, T = 200 K, (HHL) plane,
XYZ measurements on a 1cm^3 single crystal

SF NSF

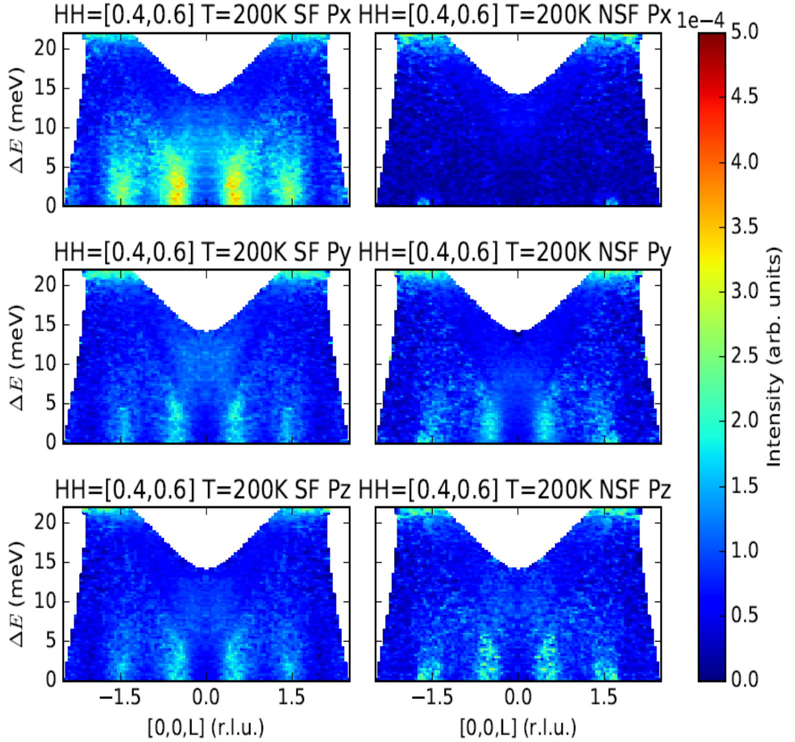
Px

Py

Pz

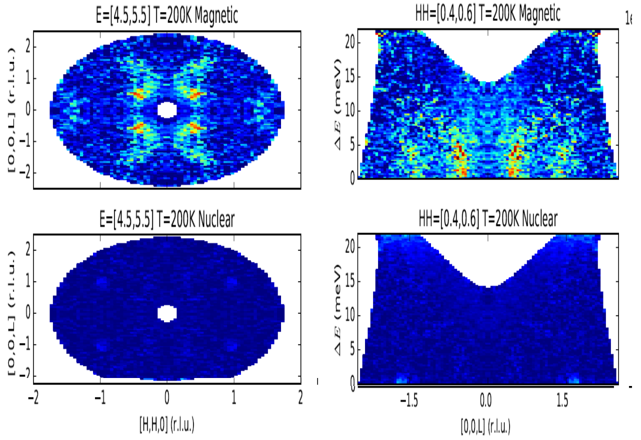


SF NSF



After applying the Scharpf angle correction

$$\left(\frac{d\sigma}{d\Omega}\right)_{mag} = 2\left[\left(\frac{d\sigma}{d\Omega}\right)_{SF}^{X} + \left(\frac{d\sigma}{d\Omega}\right)_{SF}^{Y} - 2\left(\frac{d\sigma}{d\Omega}\right)_{SF}^{Z}\right]$$



XYZ polarization analysis

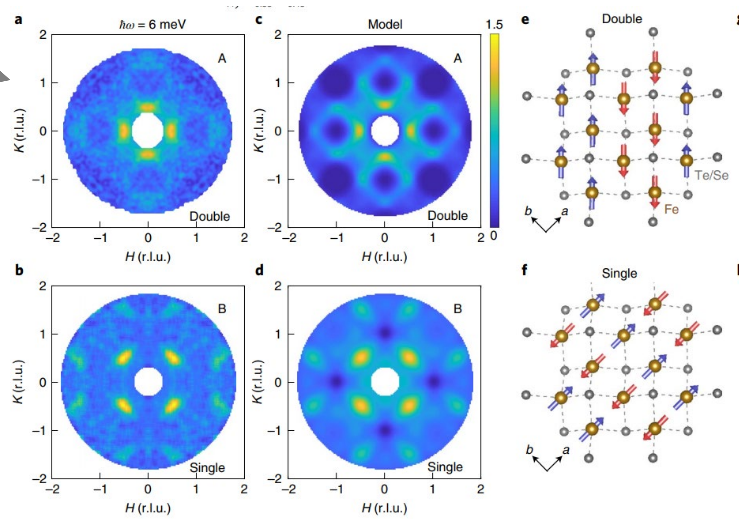
- **Dynamical spin correlations in $Fe_{1+y}Te_{0.55}Se_{0.45}$**

Y. Li, I. Zaliznyak et al. Nature Materials (2021)c

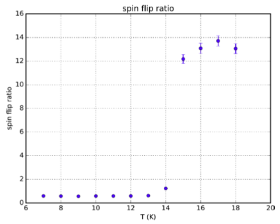
P_x (P//Q) SF/NSF polarization analysis

- two samples with different Fe content ($\Delta y \approx 0.03$): Sample A (top): NSC, and B (lower Fe content): SC below Tc=14.5 K
- models associated with the double-stripe AFM order in NSC sample A and single-stripe orders in SC sample B

$5 < E < 7$ meV (E_i = 20 meV)



- FR : order parameter for SC transition

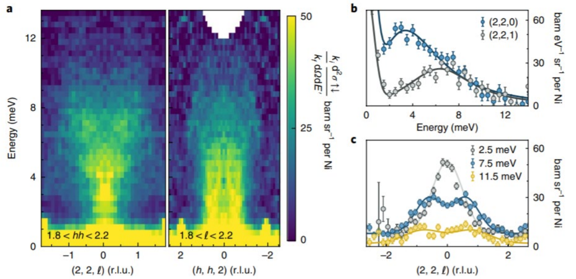


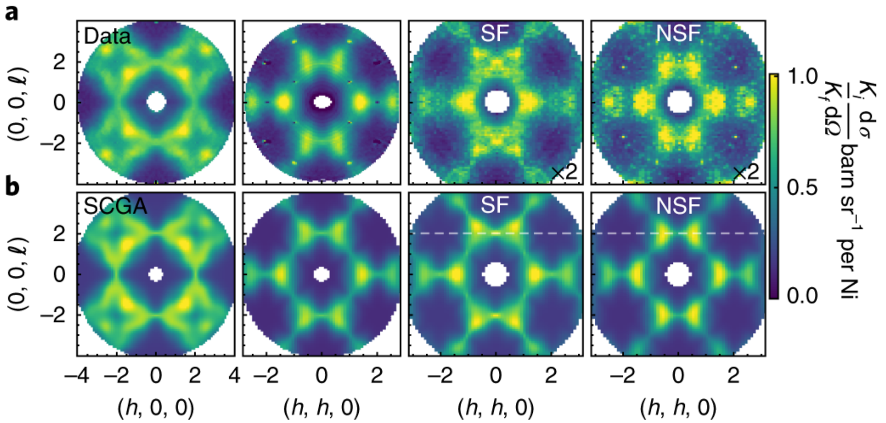
- **Continuum of quantum fluctuations in a 3D S = 1 Heisenberg magnet**

K. Plumb et al. , Nature Physics, 15, 1, 54 (2019)

P_z SF/NSF polarization analysis

- Measured excitations in $NaCaNi_2F_7$ (pyrochlore lattice) consistent with fractionalized excitations with low-energy pinch points
- Integrated signal over $0 < E < 14$ meV (E_i = 17meV)





Summary

Neutron polarization analysis implemented on modern direct geometry time-of-flight spectrometers featuring large detector arrays, provides an unprecedented range of capabilities for elastic and inelastic neutron scattering studies of novel magnetic states and excitations.

Thank you !