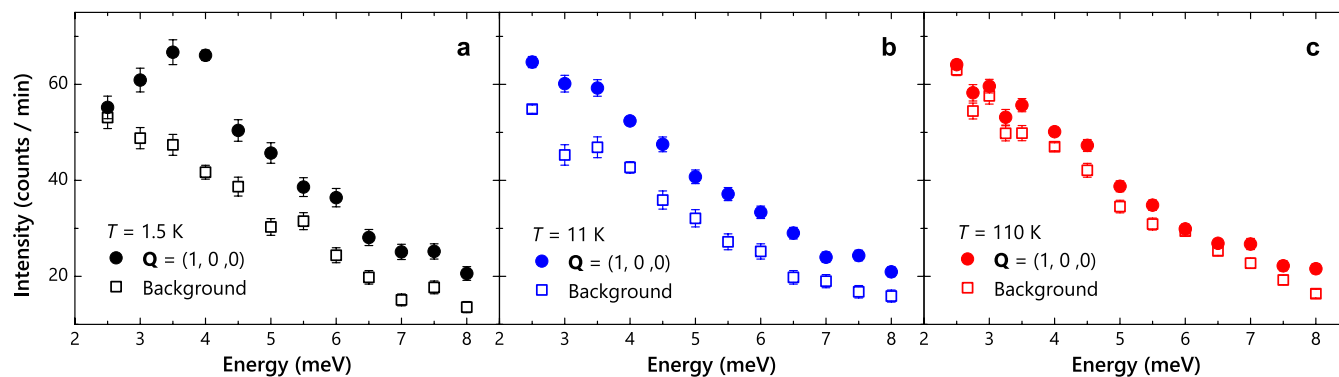
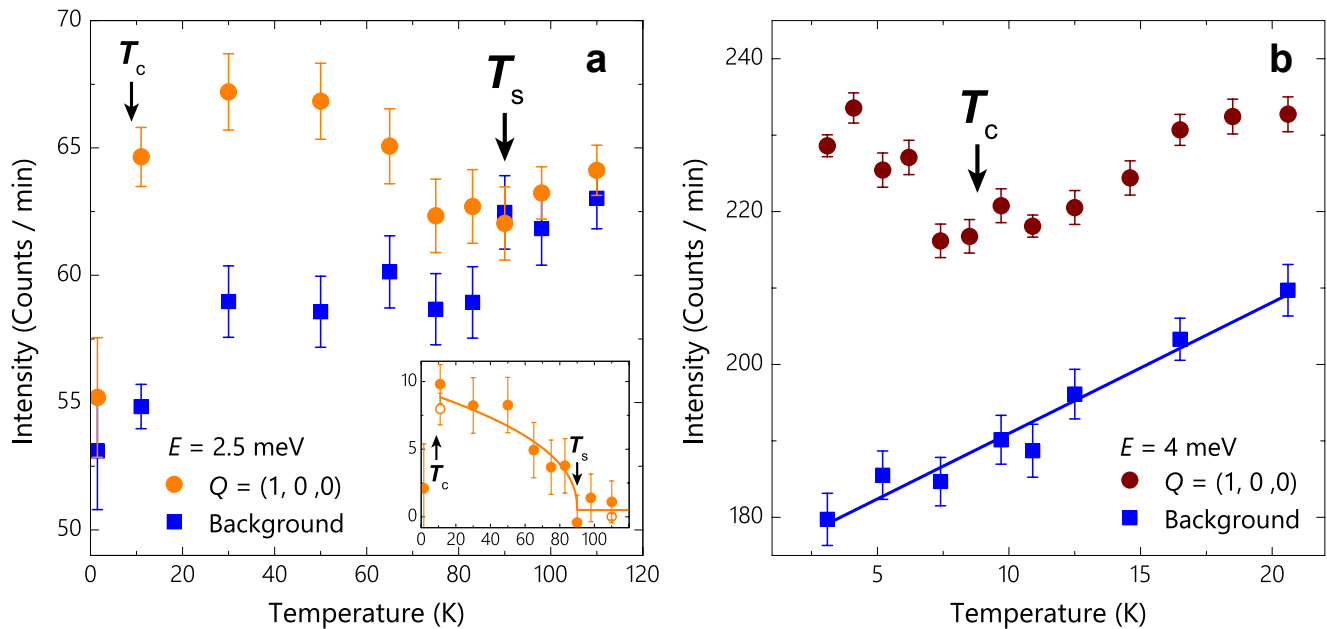


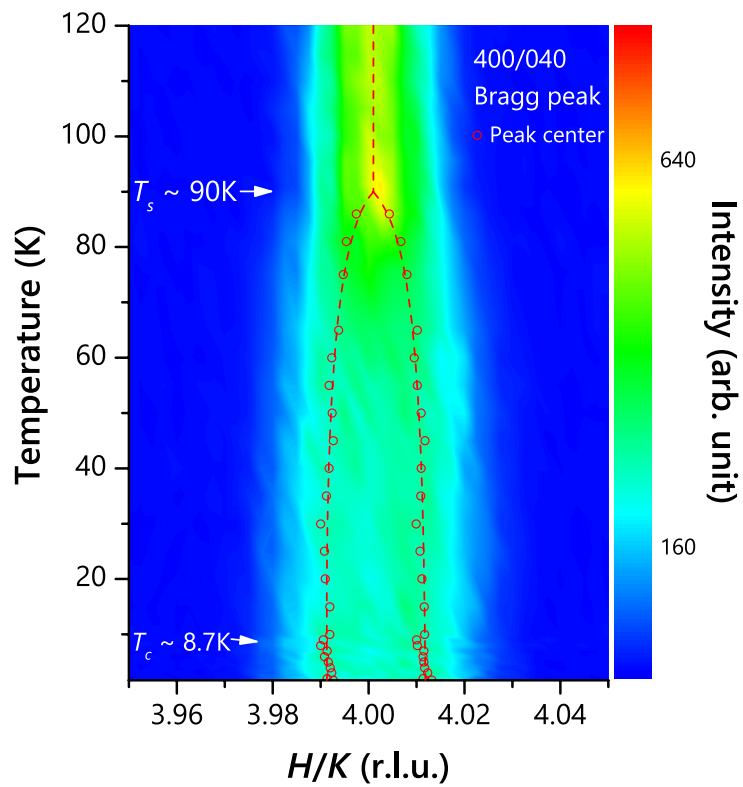
SFig 2: Representative temperature difference Q-scans [S(1.5K) - S(11K)] at 4 meV near (1, 0, 0) and (2, 1, 0). The 2D contour plot in Fig. 2e was interpolated from a series of such Q-scans. The scan directions are marked in the insets. Each scan can be fitted by a single Gaussian peak. No significant anisotropy of the peak width is observed. **a**, Rocking scan at $E=4$ meV, $Q=(1, 0, 0)$. **b**, Hscan at $E=4$ meV, $Q=(1, 0, 0)$. **c**, Hscan at $E=4$ meV, $Q=(2, 1, 0)$. **d**, Kscan at $E=4$ meV, $Q=(2, 1, 0)$.



SFig 3: Energy dependence of the scattering at the signal [Q=(1, 0, 0)] and background positions. The background was estimated as the average intensity at $Q = (0.944, 0.330, 0)$ and $Q = (0.944, -0.330, 0)$, which are marked by green arrows in SFig.1. **a**, $T=1.5$ K. **b**, $T=11$ K. **c**, $T=110$ K. The overall magnetic spectral weight is clearly enhanced on cooling from 110 K to 11 K at the energies measured.



SFig 4: Temperature dependence of the scattering at the signal $[Q=(1, 0, 0)]$ and background positions at 2.5 meV and 4 meV. The background-subtracted data are presented in Fig. 4. **a**, Temperature dependence of the scattering at the signal $[Q=(1, 0, 0)]$ and background at 2.5 meV. The background was estimated as the average intensity at $Q = (0.944, 0.330, 0)$ and $Q = (0.944, -0.330, 0)$. Although the background decreases gradually with decreasing temperature, the signal exhibits a sudden increase at $T_s=90$ K. The inset shows the background-subtracted data. The open circles are data fitted with Q -scans. We note that the decrease of the scattering intensity at the signal at 1.5 K is simply due to the opening of the superconducting spin gap. **b**, Temperature dependent data for 4 meV with the background measured at $Q=(1, 1, 0)$ and $Q=(1, -0.6, 0)$. Since this scan was measured in a relatively narrow temperature range (3K to 21K), the background was estimated by a linear fitting of the data points collected at eight temperatures (blue squares). This is justified as most data points fall on the fitting curve (blue solid line). The data presented in SFig. 4b were collected on 2T1. All other inelastic neutron scattering data were collected on IN20.



SFig 5: Temperature dependence of (4, 0, 0)/(0, 4, 0) structure peak. The 2D contour plot was interpolated from a series of Q -scans at different temperatures shown in Fig. 2a. The data were collected on 4F2.