Experimental report

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Proposal: **4-02-565**

Council: 4/2019

Title: Electronic interaction in the unconventional superconductor Sr2RuO4

Research area: Physics

This proposal is a new proposal

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Local contacts: Paul STEFFENS

Samples: Sr2RuO4

Instrument	Requested days	Allocated days	From	To
IN20	9	10	10/01/2020	20/01/2020

Abstract:

Our recent polarized INS experiments on Sr2RuO4 could for the first time quantify the quasiferromagnetic (QFM) fluctuations, which were supposed by to play the essential role in the superconducting pairing of this material. Here we propose to extend these experiments. In particular we need a better characterisation of the magnetic response near the Brillouin zone boundaries including an energy dependency. The suppression of the QFM signal with increasing q is most important to quantify the superconducting pairing and even the latest theoretical approaches find a stronger magnetic signal at the zone boundaries.

Experimental Report

Instrument	IN20
Proposal Number	4-02-565
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Experimentalist	Kevin Jenni, Yvan Sidis, Markus Braden
Local Contact	Paul Steffens

The characterization of magnetic fluctuations in Sr_2RuO_4 is crucial for understanding the superconducting pairing mechanism since different symmetries of the superconducting pairing are connected to different types of magnetic fluctuations. It has been shown that in Sr_2RuO_4 strong antiferromagnetic fluctuations originating from nesting as well as broad and weaker ferromagnetic fluctuations exist [1,2]. The weak ferromagnetic fluctuations are supposed to have a broad q dependence which gives rise to magnetic intensity also at the zone boundary. Extending our polarized INS experiments on Sr_2RuO_4 where we could quantify the quasiferromagnetic (QFM) fluctuations for the first time, we analyzed the magnetic signal at the Brillouin zone boundaries. To access a background free and purely magnetic signal we applied the full polarization analysis. Therefore we measured the spin flip channels with the magnetic field along all three directions (SFi where i=x,y,z with the usual orientation in respect to Q). The signal resulting from subtracting both SFy and SFz from two times SFx is completely of magnetic origin and represents, when corrected for magnetic form factor, bose factor and instrumental resolution, the imaginary part of the magnetic susceptibility $\chi''(q,E)$.

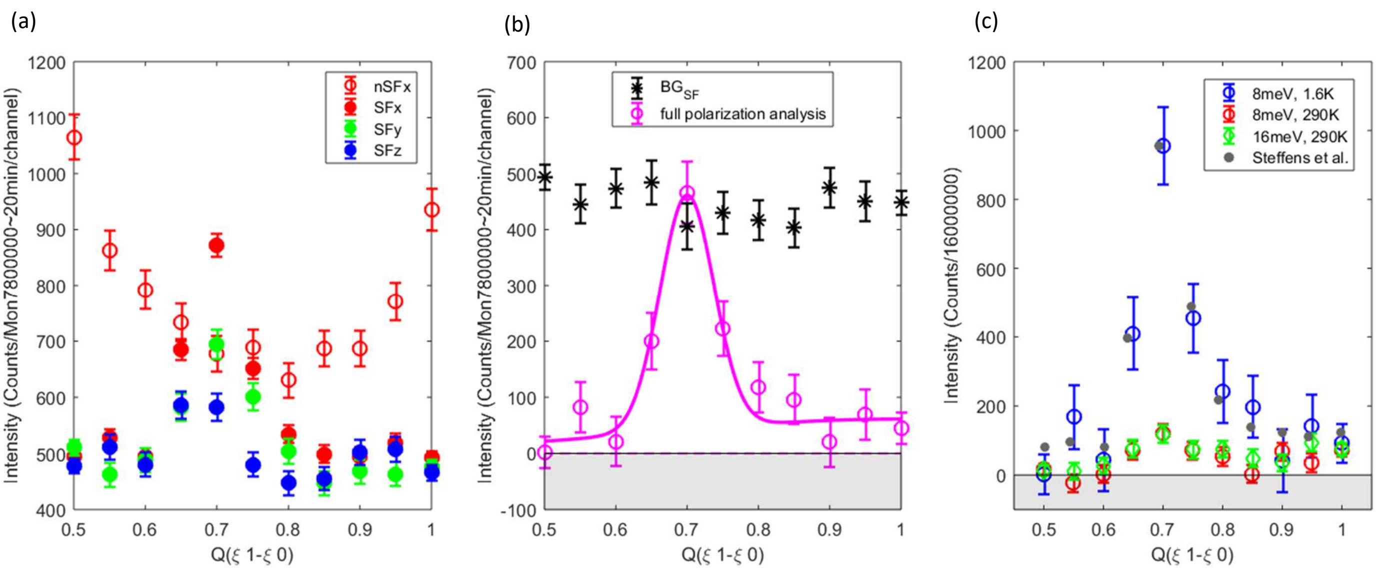

Fig. 1: Diagonal q scan over IC position (0.7 0.3 0). (a,b) Exemplary display of the polarization analysis at T = 1.6 K and E = 8 meV. The 3 SF channels (a) are combined to calculate the background free magnetic signal (b). (c) Comparison of different temperatures and energies as well as reproducibility of published results in grey. The data is corrected with the Bose factor.

Fig.1 shows the full polarization analysis on the basis of the diagonal Q scan at E = 8 meV over the incommensurate (IC) position. In (a) the three SF channels are depicted and show the reported spin anisotropy of the IC signal at (0.7 0.3 0). The magnetic signal in (b) obtained by the mentioned calculation peaks at the IC position and is non zero at the zone center (1 0 0). The measurement confirms the previously reported findings in Steffens et al. [2] (see Fig.1c). We repeated this diagonal Q scan at different temperatures and energies. At 290 K the IC signal drops significantly whereas the QFM signal at (1 0 0) stays nearly constant. Furthermore there is no sizeable intensity measureable at (0.5 0.5 0), which represents the zone boundary X point of the first Brillouin zone. This scan clearly confirms that the quasiferromagnetic contribution to the susceptibility still exhibits a finite q-width in contrast to the recent DMFT calculations which suggest a more local ferromagnetic character.

To investigate the zone boundaries further we collected data for different energies and Q vectors representing the Γ, X, and M point as well as the IC position. Also here we deploy the full polarization analysis to extract the possibly very weak magnetic signal (Fig.2).

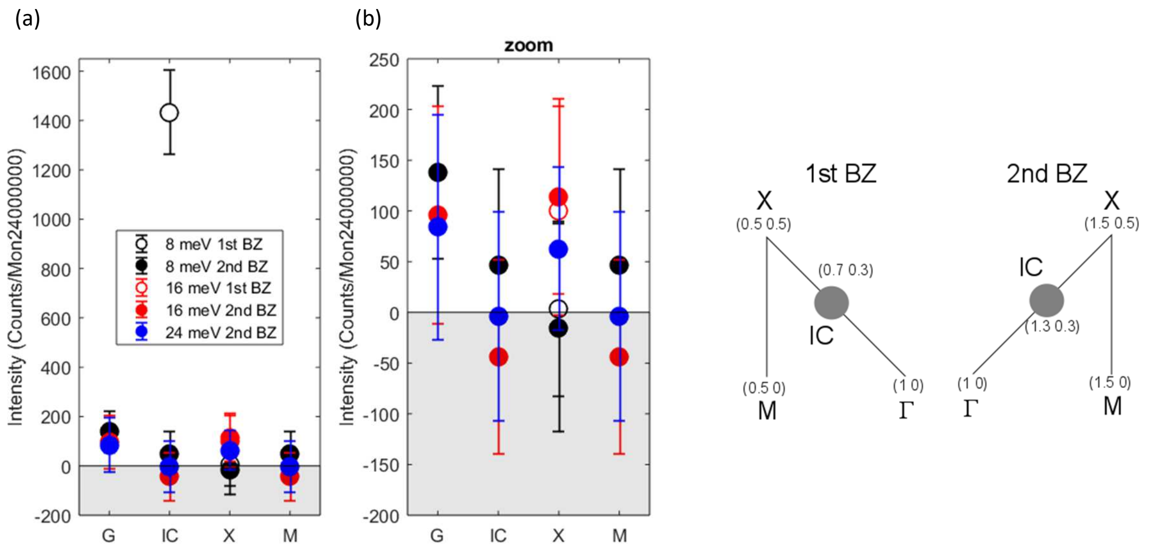

Fig. 2: Magnetic signal at specific points in Brillouin zone derived from full polarization analysis. The data is not corrected for the magnetic form factor.

Unfortunately the data does not give clear evidence of magnetic intensity at the zone boundaries due to the limited statistics, which we could obtain in spite of the rather large single-crystalline volume used. All points lay around zero within their error bars. Although every point was counted with a minimum of 4.5 hours the statistic is not sufficient to make a clear statement.

During the beam time we experienced technical difficulties as the instrument was not operable because of an electronic problem of the automatic block control. Therefore the experiment had to be stopped for 2.5 days. Since the counting time is very crucial for this experiment the missed beam time had a great impact on the results.

In addition we found an increased background in comparison to the previous experiment at IN20. We assign this to enhanced incoherent scattering originating from the copper sample mounting in comparison to the aluminum one used in the earlier experiment. This was especially surprising since we used the same sample setup for a previous experiment at THALES, where we did not encounter this background problem and where the use of Cu was required in order to cool into the superconducting state. Possibly the better resolution at the cold TAS lead to less incoherent scattering collected.

In conclusion reliable estimates on the strength of magnetic scattering at the Brillouin zone boundaries could be obtained only at higher temperature, where we confirm considerable suppression of the quasiferromagnetic signal at the zone boundary, see [2].

References

[1] Y. Sidis et al., Phys. Rev. Lett. 83, 3320 (1999) ; M. Braden et al., Phys. Rev. B 66, 064522 (2002); M. Braden et al., Phys. Rev. Lett. 92, 097402 (2004).
[2] P. Steffens, Y. Sidis, J. Kulda, Z. Q. Mao, Y. Maeno, I. I. Mazin, and M. Braden, Phys. Rev. Lett. 120, 047004 (2019).