Experimental report

13/03/2019

Proposal: **4-02-537** **Council:** 4/2018

Title: Interplay of magnetic excitations and superconductivity in Sr2RuO4

Research area: Physics

This proposal is a new proposal

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Experimental team: Kevin JENNI

Local contacts: Paul STEFFENS

Samples: Sr2 Ru O4

Instrument	Requested days	Allocated days	From	To
THALES	7	5	02/10/2018	07/10/2018

Abstract:

Recent experiments on THALES using a large sample of superconducting Sr2RuO4 were successful in following the SDW antiferromagnetic signal into the superconducting state for energies well below twice the superconducting gap. The absence of a change induced by superconductivity unambiguously excludes that the nesting and the quasi-1-dimensional bands are the active parts. Therefore it is most interesting now to search for an impact on the quasiferromagnetic fluctuations using the same experimental setup.

Experimental Report

Instrument	THALES
Proposal Number	4-02-537
Proposal	Interplay of magnetic excitations and superconductivity in Sr_2RuO_4
Experimentalist	Kevin Jenni, Markus Braden
Local Contact	Paul Steffens

The superconducting (SC) state in Sr_2RuO_4 is not yet understood. The proposed triplet p-wave pairing arises from quasi-ferromagnetic (FM) fluctuations. However, the dominant magnetic excitations are incommensurate (IC) fluctuations originating from strong nesting in the Q1D bands [1]. These fluctuations do not seem to play an active role in the SC pairing [2]. Polarized INS experiments have shown that there exist quasi-FM fluctuations indeed which are significantly weaker than the IC ones and widely spread in Q-space [3]. In this experiment we wanted to further investigate the magnetic fluctuations in Sr_2RuO_4 in respect to their l dependence. The magnitude of magnetic fluctuations should increase in the SC state since the opening of the SC gap is supposed to enhance magnetic signal like a resonance mode.

To reach the low background, the high energy resolution and the high flux needed for the described task we measured at THALES in following configuration. The Si/PG monochromator-analyzer setup delivered the high energy resolution whereas the background could be minimized by installing the Be-filter as well as the radial collimator at the analyzer. At first, the use of the Be-filter turned out to tamper with the energy scaling depending on the scan direction. Due to the increased weight of the analyzer table by using the Be-Filter it came to position errors of the motors. This could be resolved by increasing the air pressure of the air pads.
Another issue with the experimental setup lead to an increased background for certain detector positions (a4). For some Q-space positions the detector would be positioned in the direct beam directions and collect gamma radiation despite of the installed shielding. These influence of gamma radiation became visible in our measurements due to high counting times of 20 min per point. We had to apply more shielding. The heavy lead blocks could not be attached to the detector why they had to be deployed in front of the detector on a table and removed depending on the scan.

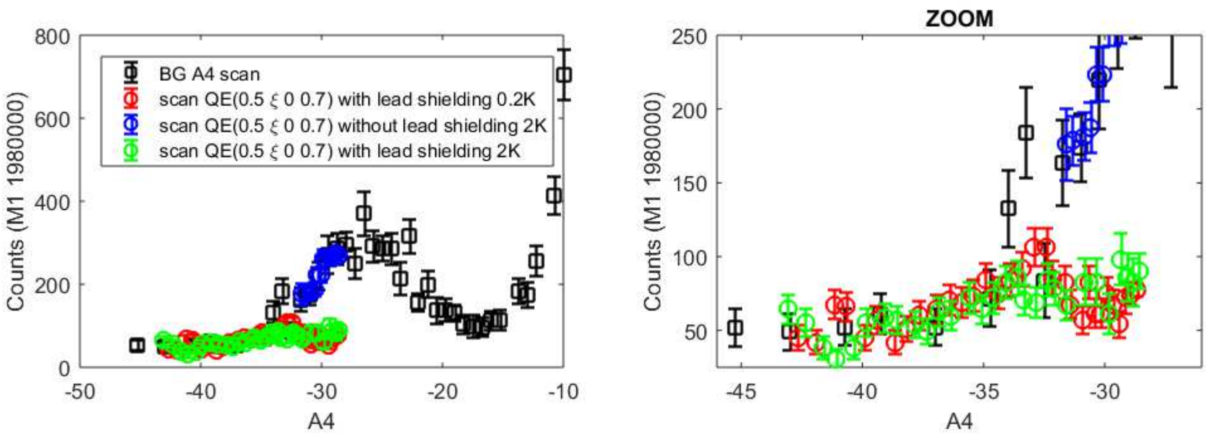

Fig. 1: Signal depending on the a4 motor position (detector) with and without lead shielding

Fig. 1 displays the influence of the lead shielding on the background signal depending on the detector position a4. This issue causes an alleged peak in the scan over Q(0.5 ξ 0) at E = 0.7 meV (red points). The peak originates from the movement of the detector relatively to the lead shielding. The background increases due to gamma radiation hitting the detector and decreases as soon the detector is moving behind the lead shielding. This analysis shows that the shielding was not effective enough for the a4 position around -33. All data has to be carefully analyzed in terms of this critical a4 position.

At T = 0.2 K (T_C = 1.5 K) the magnetic positions corresponding to the nesting vector (0.3 0.3 0) and the zone boundary (0.5 0.5 0) were investigated by rocking scans at energies around 1 meV. The zone boundary scan showed no peak whereas the rocking scans at positions (0.3 0.7 0) and (0.7 0.7 0) indicated the expected peaks. We decided to study the l dependence of the nesting positions by using energy scans (see figure 2 & 3). The same scans are done at T = 2 K in the normal state (NS) and at a different Q position as background measurement.

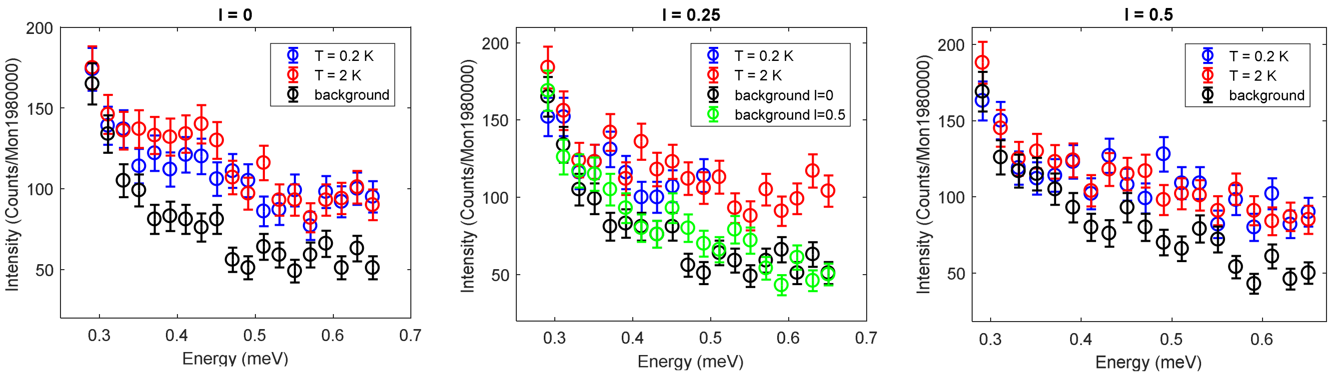

Fig. 2: Energy scans at Q(0.3 0.7 l) in SC and NS for l = 0, 0.25, 0.5 including the corresponding background.

In the energy scans at Q(0.3 0.7 l), the magnetic signal is clearly visible for all l values. It does not change significantly in intensity for different l values which confirms the two dimensional character of the bands. An enhancement of magnetic signal in the SC phase is definitely not present. For the equivalent position (0.7 0.7 l) the magnetic signal is clearly reduced and can barely be seen out of the statistical error (see figure 3). The reduction of magnetic signal at higher Q is expected because of the magnetic form factor.

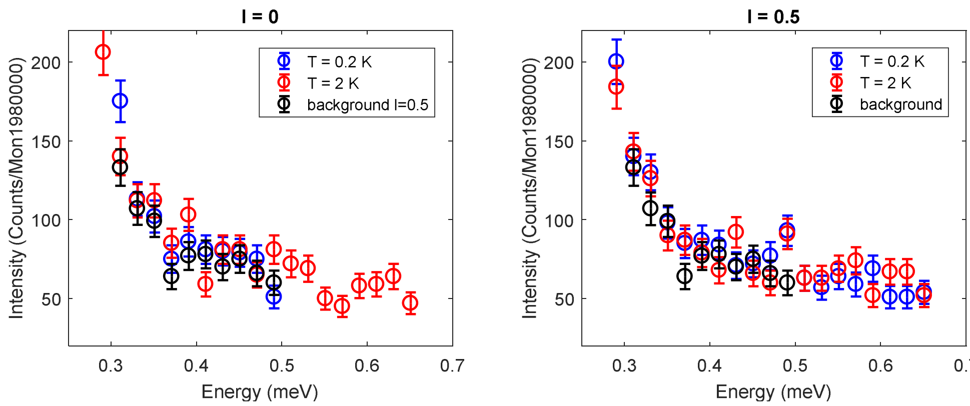

Fig. 3: Energy scans at Q(0.7 0.7 l) in SC and NS for l = 0, 0.5 including the corresponding background.

For better comparison of data in the SC and NS, we subtracted the background and corrected the signal with the Bose factor (see figure 4). The pure magnetic signal increases as expected with energy. There is no significant difference between the two l values as well as the two temperatures. The magnetic signal is not enhanced in some form of resonance mode at low temperatures. Also the comparison of the data at different l values yields no clear difference out of the statistical error.

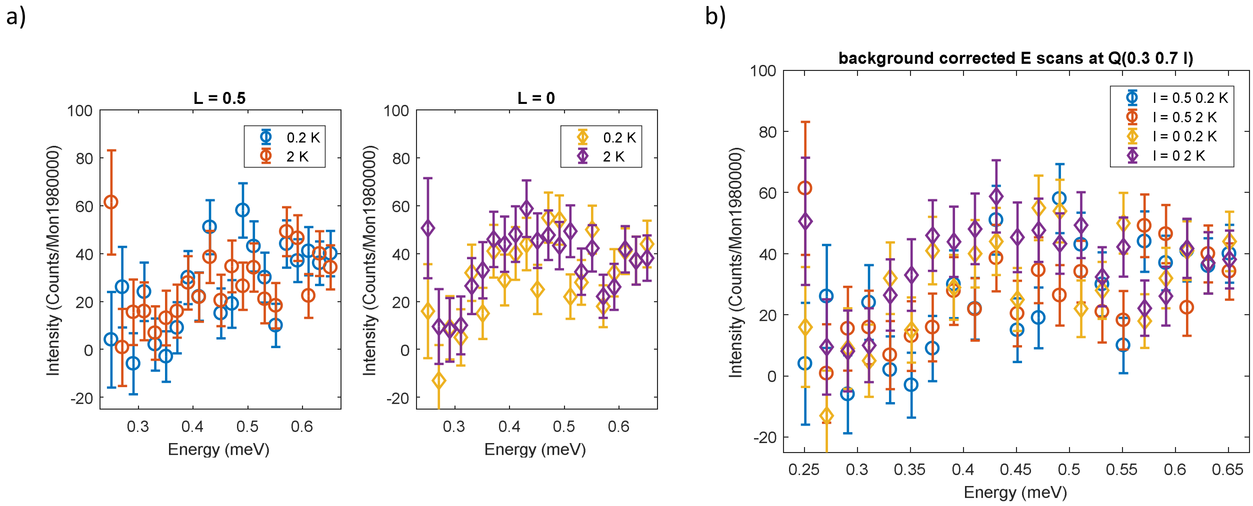

Fig. 4: a) Energy scans at Q(0.3 0.7 l) in SC and NS corrected for background and Bose factor. b) Comparison of data above.

Following an idea mentioned in a private communication with I. Mazin, we checked also for a magnetic signal at the zone boundary Q(0.5 0.5 0) (Fig. 5). The energy scan at low temperature shows no significant signal and also in the rocking scans at 0.5 and 1 meV (without Be-filter) is no peak visible. Because of the lack of signal and the time constraint, we did not further investigate this Q position.

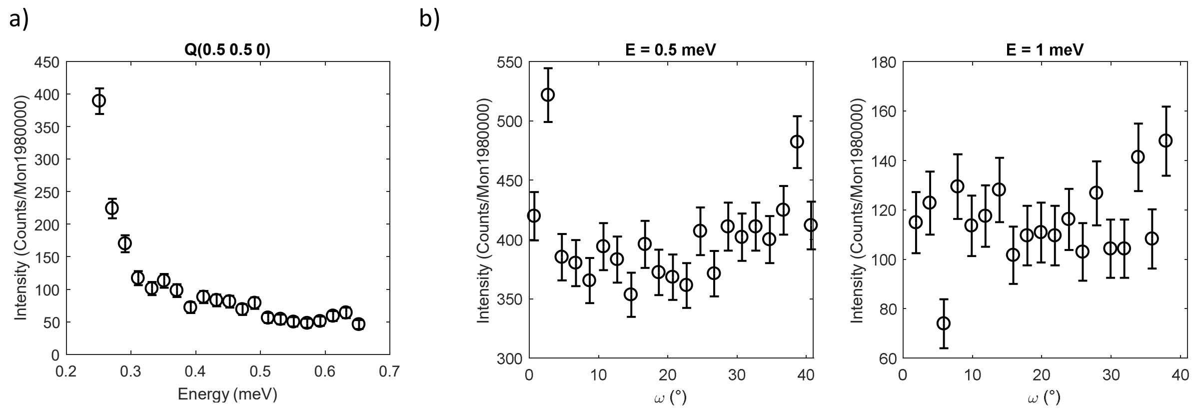

Fig. 5: search for magnetic signal at the zone boundary: a) energy scan shows no significant increase of signal towards higher energies, b) Rocking scans at Q(0.5 0.5 0) for different energies.

We can conclude that there is no strong l dependence of the magnetic signal at the nesting positions. This is in agreement with the two dimensional character of the system. Also the temperature or rather the SC state has no influence of the magnitude of the signal. There is no resonance mode visible. This experiment is very difficult because of the weak magnetic fluctuations ones wants to investigate. Although we used a large crystal mass of 12 g the data collection was still time consuming. The setup problems with the faulty motor positions and the insufficient shielding shortened our usable beam time.

References

[1] Y. Sidis et al., PRL 83, 3320 (1999); M. Braden et al., PRB 66, 064522 (2002); F. Servant et al., PRB 65, 184511 (2002); M. Braden et al., PRL 92, 097402 (2004); K. Iida et al., PRB 84, 060402(R) (2011); K. Iida et al., J. of Phys. Soc. Jpn. 81, 124710 (2012).
[2] S. Kunkemöller et al., PRL 118, 147002 (2017).
[3] P. Steffens, Y. Sidis, J. Kulda, Z. Mao, Y. Maeno and M. Braden PRL 120, 047004 (2019).