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Fe-based superconductors vs frustration

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During my stay at PSI I have dealt mainly with two different muSR experiments: 1) Spin dilution in $LaFe_{1-x}Ru_xAsO$ and 2) Effect of pressure on the magnetic properties of REFeAsO with RE=La, Ce, Pr, Sm.

1) Spin dilution in $LaFe_{1-x}Ru_xAsO$

This material is a model system to study the magnetic frustration of a metallic compound. Indeed it has been observed that the Fe ions in the Fe-based superconductors form a J1-J2 square lattice, namely a lattice where the similar nearest neighbour and next-nearest neighbour hopping integrals can give rise to competing exchange couplings and, hence, to frustration [2-4]. Accordingly, the pnictide LaFeAsO parent compound offers now the possibility to investigate the effect of frustration in the J1-J2 model when the electrons become delocalized.

During my stay at PSI, I have dealt with a muSR seperiment at the GPS beam line whit the aim of studying the effect of the spin dilution on the square magnetic layer of $LaFe_{1-x}Ru_xAsO$ pnictide system. The spin dilution has been accessed by means of the isovalent substitution of Fe with the spinless Ru. The main goal of the experiment was to discriminate whether the LaFeAsO pnictide behaves either as a simple non frustrated spin-diluted square lattice or as a J1-J2 square frustrated system. The principal indicator which can help us to discriminate between these two main possibilities is the critical Ru content necessary to destroy the magnetic ordering. For the validity of the simple dilution model, the disappearance of the long-range magnetic order is expected at the classical percolation threshold close to x=0.4, e.g. such as for Zn doped $LaCuO_4$. In a frustrated two-dimensional S=1/2 Heisenberg antiferromagnets on a square lattice, at first, one would expect that the enhancement of quantum fluctuations leads to a suppression of the long-range order well below the percolation threshold. However, one should also consider that, owing to the next nearest-neighbor coupling, the percolation threshold extends to much larger doping levels with respect to non-frustrated antiferromagnets. Indeed, in the J2-J1 Li_2VOSiO_4 system the long range antiferro order is destroyed for x=0.6, as demonstrated by achieving the spin dilution by means of the V/Ti substitution [1].

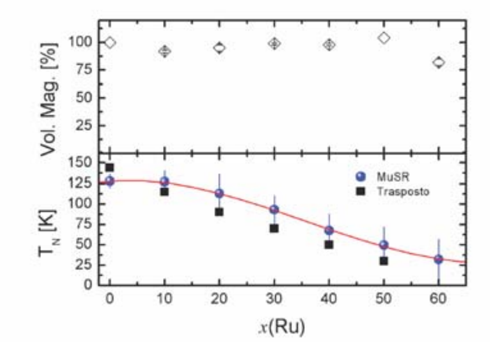

Fig1. Magnetic volume fraction (top) and Neèl temperature (bottom) of $LaFe_{1-x}Ru_xAsO$ as a function of the percentage of Fe/Ru substitution.

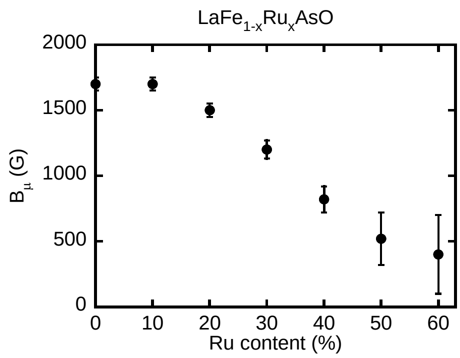

Fig.2 Internal field at the muon site, proportional to the staggered magnetization, as a function of Ru content from Zero Field muSR at 5 K.

In fig1. it is shown the behaviour of the magnetic volume fraction (upper panel) as a function of the Ru content in $LaFe_{1-x}Ru_xAsO$, as obtained by the muSR measurement during my stay at PSI. It is clearly shown that the volume fraction starts to deviate from the unity around 60% of Ru substitution. In addition a progressive reduction of the Neèl temperature (lower panel) is observed as Ru content is increased and the threshold for the disruption of the magnetic order seems even higher than 60%. Accordingly, fig.2 shows that the internal field at the muon site, proportional to the staggered magnetization, is suppressed above x=0.6. This experiment shows that the simple non frustrated dilution model cannot be applied to the Fe-based parent compound. A continuation of this experiment should consider to study compounds with higher Ru content in order to measure the real amount necessary to completely destroy the magnetic ordering.

[1] N. Papinutto Phys. Rev. B 71, 174425 (2005)
[2] Q.Si and E. Abrahams, Phys. Rev. Lett. 101, 076401 (2008)
[3] H. Lee et al., Phys. Rev. B 81, 220506(R) (2010)
[4] B. Schmidt et al., Phys. Rev. B 81, 165101 (2010)

2) Effect of pressure on the magnetic properties of REFeAsO with RE=La, Ce, Pr, Sm.

Besides carrier doping, it also turns out that applied pressure can induce superconductivity in the undoped parent phases. The existence of the pressure induced superconducting phase indicates that subtle changes and/or contractions of the structure can switch on superconductivity from a spin density wave (SDW) phase. However, the mechanism of pressure induced superconductivity is very poorly understood, and more detailed studies are required to clarify the effects of applied pressure on the electronic properties of iron-based high temperature superconducting systems. Most of the past experimental studies of these pressure effects, however, have focused on the effect of pressure on the superconducting phase (see Ref. 1 for a review). Almost *no experimental* studies have been reported for the undoped parent compounds, at least respect to the effect of pressure on their *microscopic* magnetic properties.

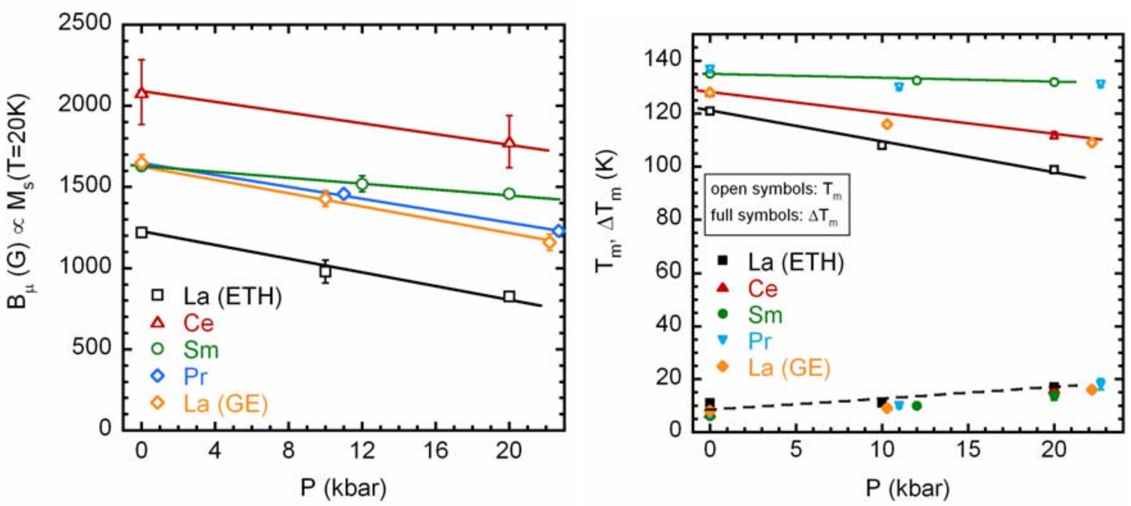

Fig3. Pressure dependence of the internal muon field (left), proportional to the staggered magnetization, and of the spin density wave magnetic transition and its width (right) of REFeAsO for different RE. The sample labelled ETH have been synthesised under high pressure, all the others under ambient pressure conditions.

During this stay at PSI, I have dealt with a muSR experiment on the GPD spectrometer with the aim of studying the effect of external pressure on the magnetic ground state of REFeAsO compound for different rare earths RE=La, Ce, Pr, Sm. The evolution of the internal muon field, proportional to the staggered magnetization, and of the spin density wave magnetic transition are displayed in Fig.3 as a function of pressure for different RE. The data display a complex RE dependent behaviour which is now under consideration along different lines: frustration effects [2], change of the Fermi surface nesting [3], RE dependence of the structure of the magnetic array [4]. Parallel ab-initio calculations are underway.

[1] C.W. Chu and B. Lorenz, cond-mat/0902.0809
[2] G.S. Uhrig et al., Phys. Rev. B 79, 092416 (2009)
[3] A. N. Yaresko et al., Phys. Rev. B 79, 144421 (2009)
[4] H. Maeter et al., Phys. Rev. B 80, 094524 (2009)