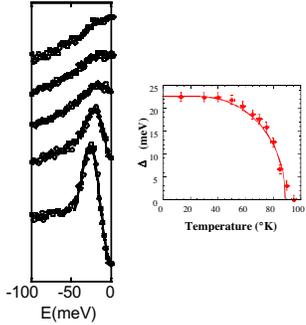


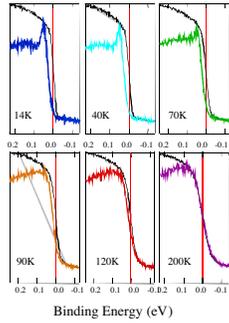
Time-Reversal Symmetry Breaking in High- T_c Superconductors

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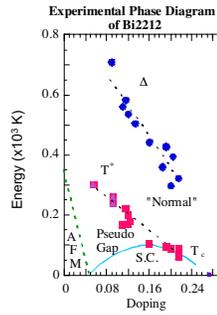
Motivation: The superconducting transition in overdoped HTSCs is mean-field-like, but in underdoped samples the behavior is far from mean-field



In overdoped samples, the superconducting gap evolves in a mean-field manner.



In underdoped samples on the other hand, a pseudogap is formed far above T_c



The energy scales of the two gaps are related, so the pseudogap might be the precursor to superconductivity

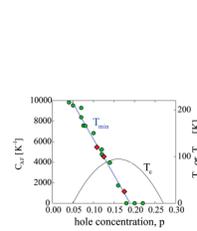


Fig. 6. The doping dependence of the position, T_{min} , of the minimum in $a-b$ plane resistivity for La-214 (●) and of the amplitude C_0 of short-range AF correlations (◆) determined from the ratio T_{min}/T_c using Eq. (4).

However, heat capacity measurements suggested that they might have different origins

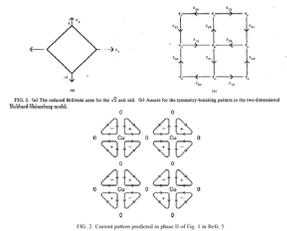


Fig. 8. Crystal patterns predicted by phase II of Fig. 1 in Refs. 5 and 6.

Some models predict that due to strong correlations, electrons hop in a coordinated way. These patterns break time reversal symmetry. We will therefore look for TRS breaking with ARPES.

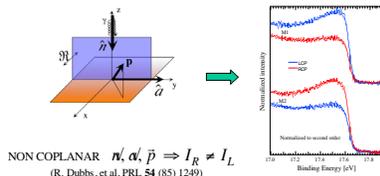
Results

ARPES can test for TRS breaking by using an axial vector- circularly polarized light-which gives an intensity proportional to

$$M_L = \langle \hat{p} | O_L | \psi_k \rangle$$

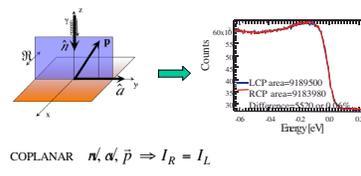
We look for circular dichroism

$$D = I_R - I_L \propto |M_R|^2 - |M_L|^2$$



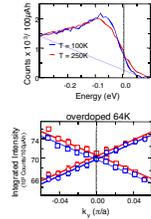
NON COPLANAR $\hat{n}, \hat{\alpha}, \hat{p} \Rightarrow I_R \neq I_L$ (R. Dubbs, et al. PRL 84 (85) 1249)

When the directions of the light, the outgoing electron, and the mirror plane are not co-planar, there is a geometric dichroism

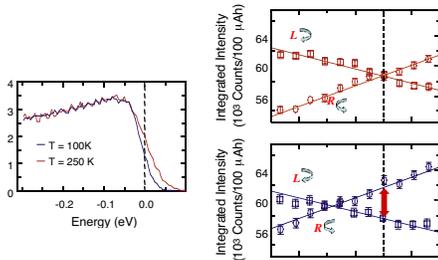


COPLANAR $\hat{n}, \hat{\alpha}, \hat{p} \Rightarrow I_R = I_L$

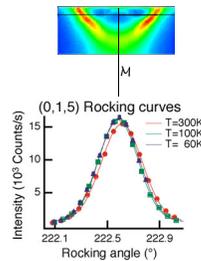
The experiment has to be done when all these three directions are co-planar



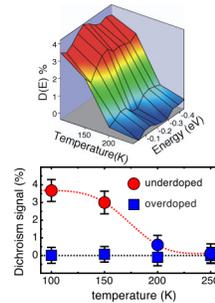
Overdoped samples show no dichroism



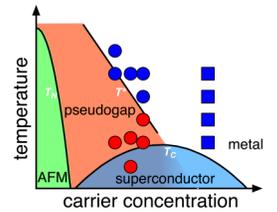
When an underdoped sample enters the pseudogap state, there is **dichroism!**



We have checked that this is not simply due to parity violation, i.e. motion of the mirror plane



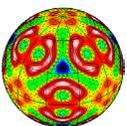
The energy and temperature dependence of the effect.



The doping dependence of the Effect, which is clearly tied to the pseudogap.

High temperature superconductors can tell right from left!

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