ARPES results from CLBLCO single crystals

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Collaborations

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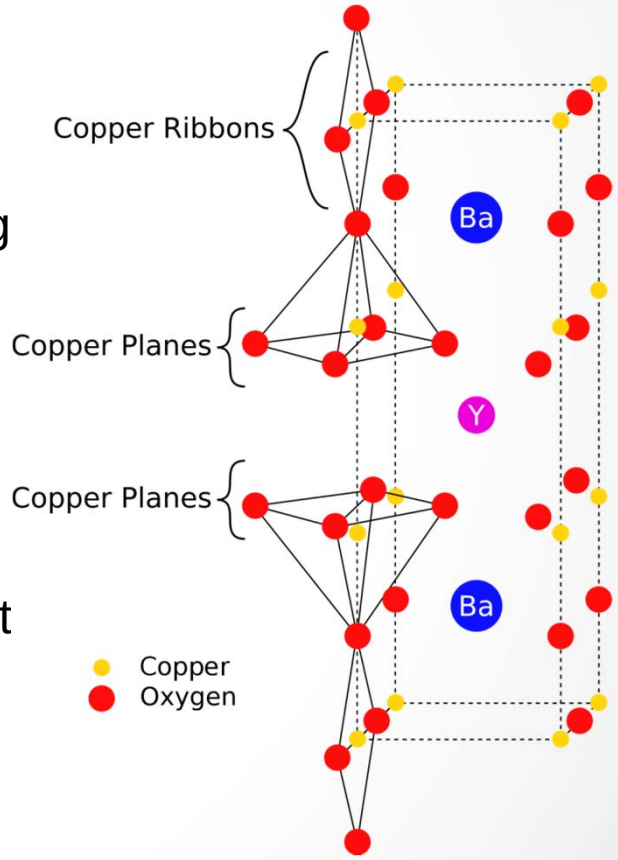
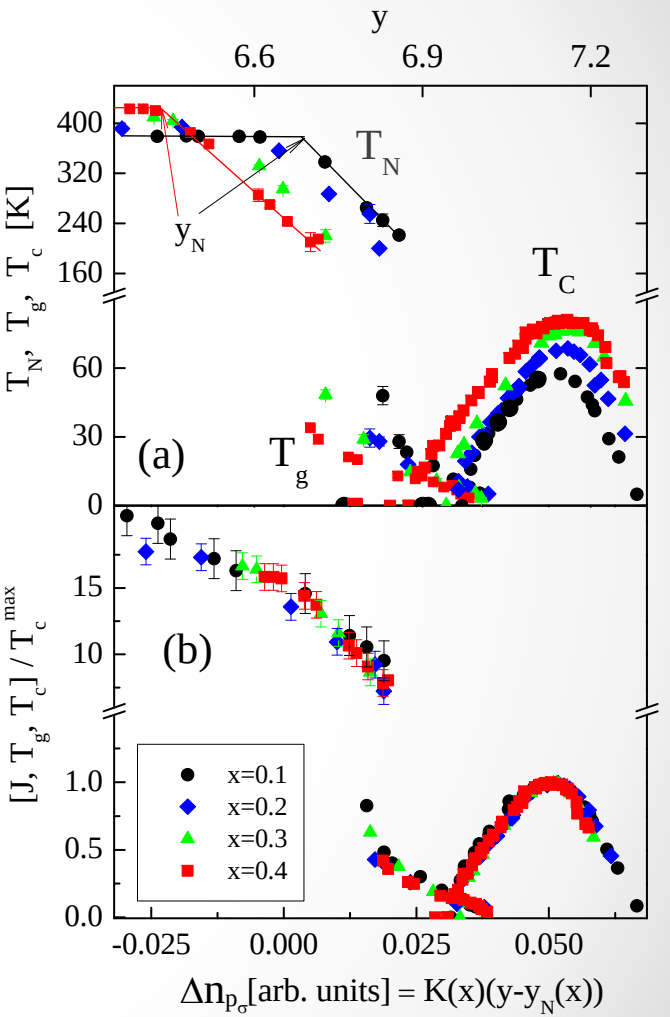
$(Ca_xLa_{1-x})(Ba_{1.75-x}La_{0.25+x})Cu_3O_y$

- A well studied High T_c system which was synthesized first here in the **Technion.**
- The structure of CLBLCO is similar to YBCO(1:2:3), but it is tetragonal for all doping (y) and temperature range.
- In the chemical formula, Ca to Ba ratio, controlled by x, defines the Family.
- Oxygen, y, controls the doping – The amount of holes in the plane.
- With oxygen doping we can tune the compound from an insulating AF to a superconductor.



The Unified Phase Diagram

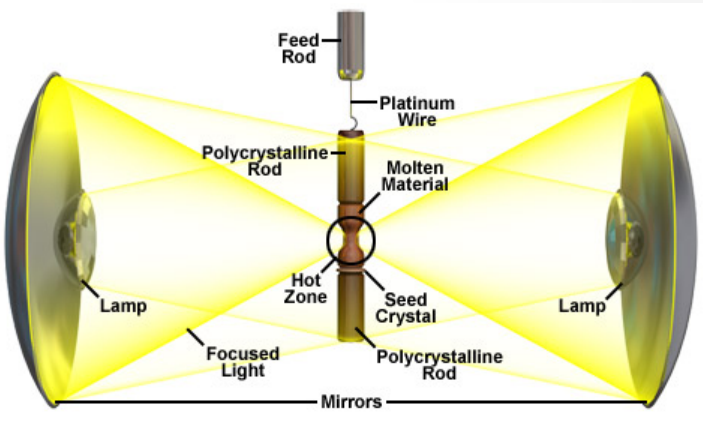
- Four CLBLCO Families, x=0.1,..,0.4
- By Increasing ***x***, the maximum T_c is increased by 30% between different families.
- As x increases, the Cu-O-Cu bond becomes straighter and shorter = Increase in the super-exchange interaction.
- The four phase diagrams can be scaled to one.
- Drawbacks:
  - **Powder Measurements**
  - **J** is extracted from T_N using **theoretical calculations.**



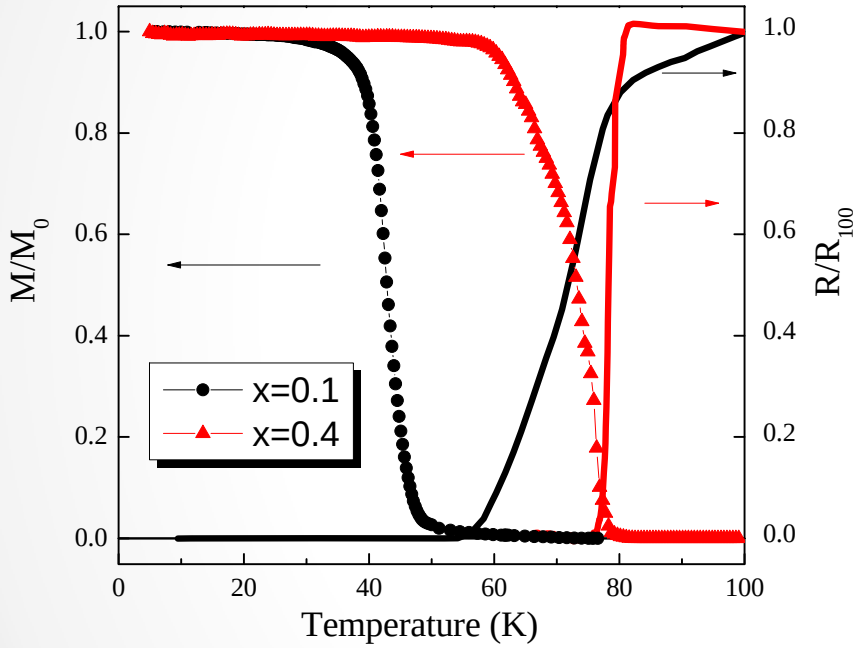
$T_c \propto J$

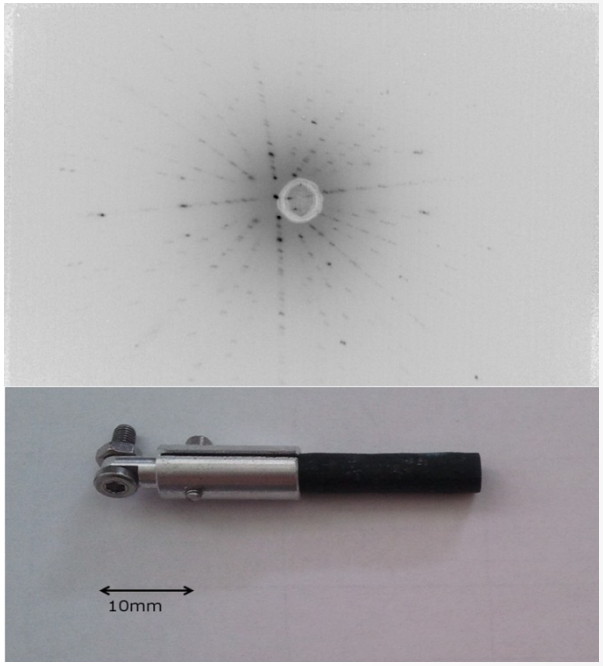
The Crystal growth technique we use

Traveling Solvent Floating Zone Method (Crystal Systems Corp. Japan) image furnace. It is in operation in our laboratory since 2007.



Sample characterization

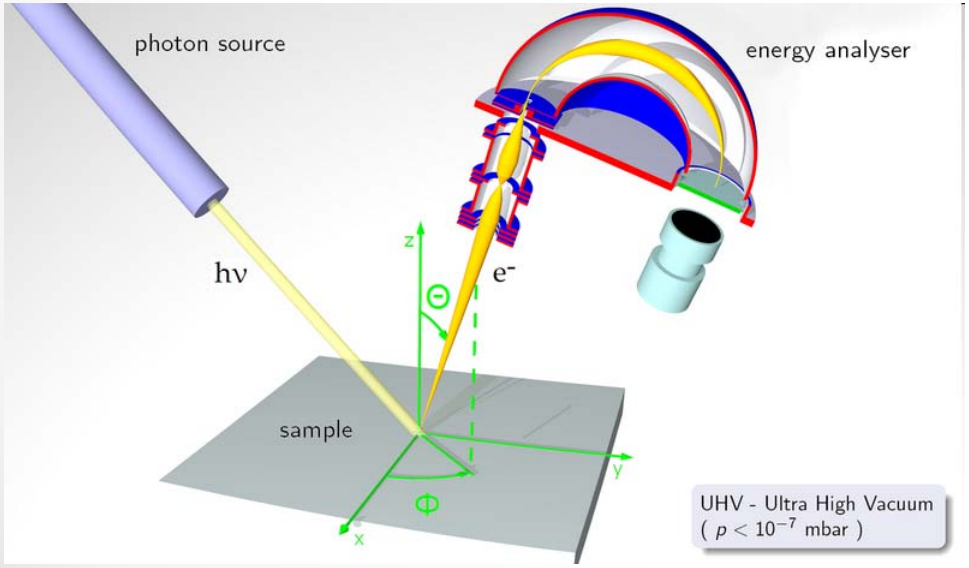




Resistivity and susceptibility are consistent with powder measurements

Angle Resolved Photo Emission Spectroscopy

- A freshly cleaved sample is illuminated by a beam of monochromatic UV light.
- Due to the photoelectric effect, the sample emits electrons.



$$E_k = h\nu - \phi - |E_B(k)|$$

$$|k_{||}| = \frac{\sqrt{2mE_k}}{\hbar} \sin\theta$$

Angle Resolved Photo Emission Spectroscopy

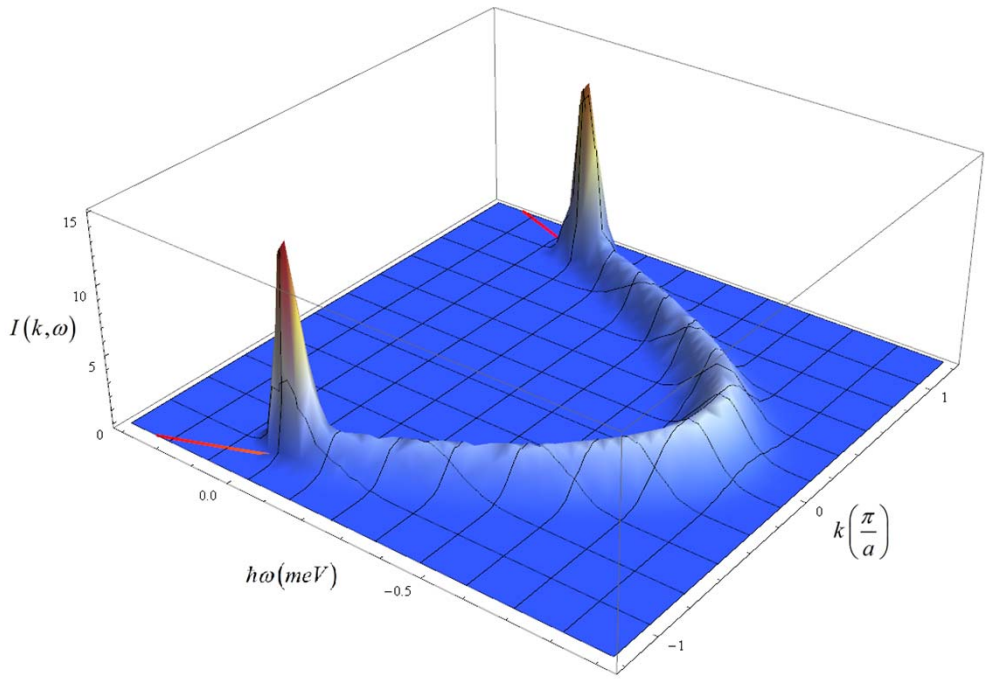
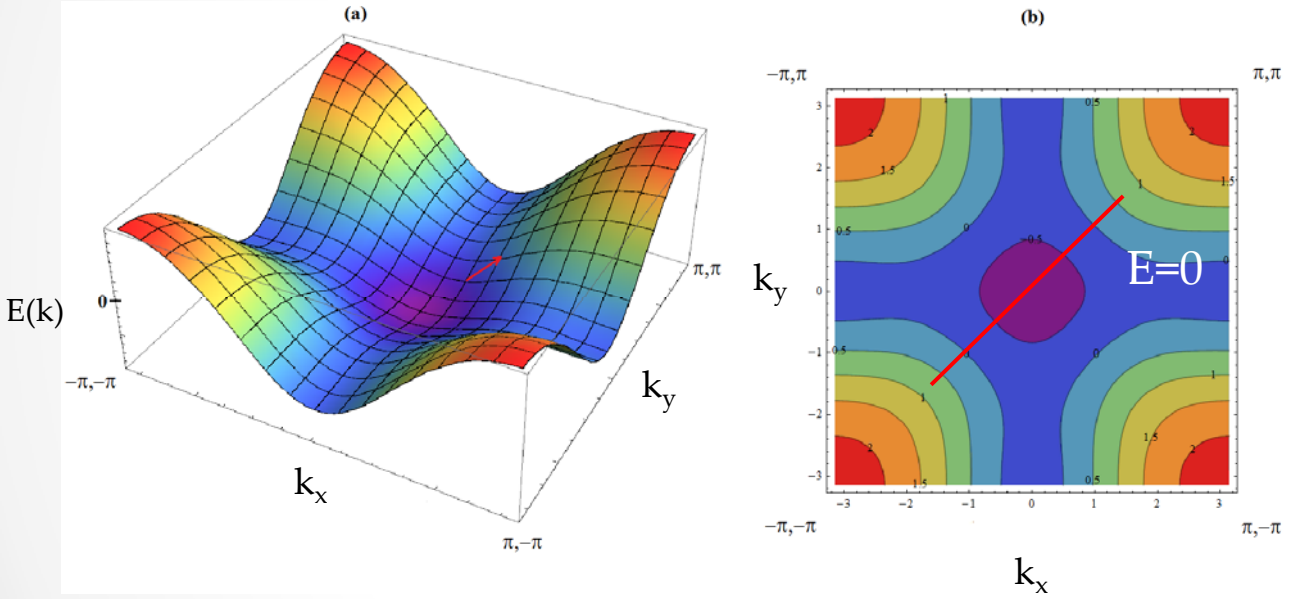


Illustration of the data acquired by the analyzer in ARPES in a cut along the π,π direction

- $I(\boldsymbol{k},\boldsymbol{\omega})$ measured in ARPES is proportional to number of electron with a given ***k*** and E(***k***).
- A lorentzian in **k** and E(***k***) following the dispersion relation is expected.
- The width of the lorentzian corresponds to the life time and correlation length of the quazi-particles.

Fermi Surface and velocity in cuprates

- Generally for cuprtaes, the energy dispersion of electrons is described by a tight binding model.



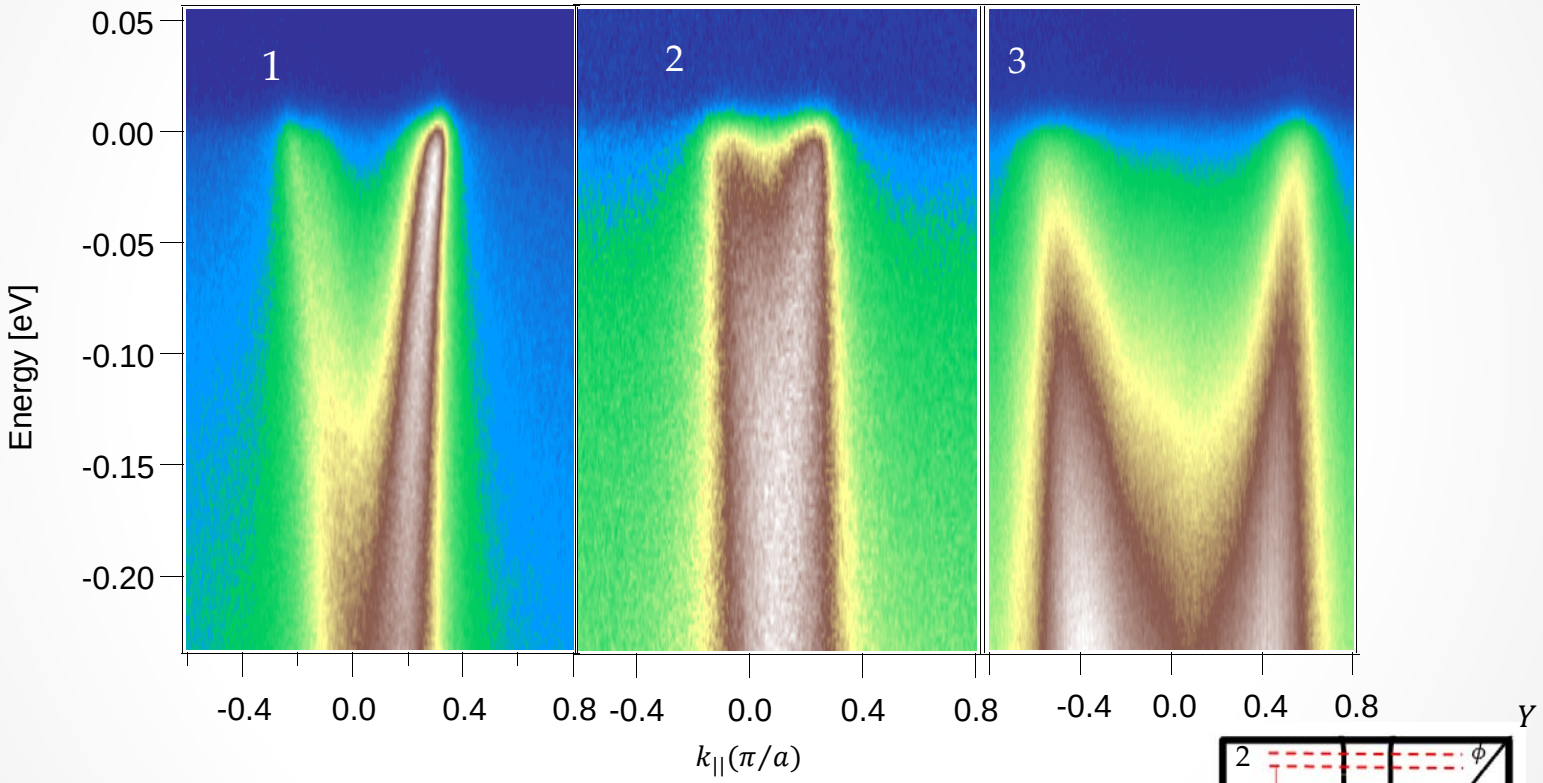
The red arrow represent v_f in the π,π direction at k_f.

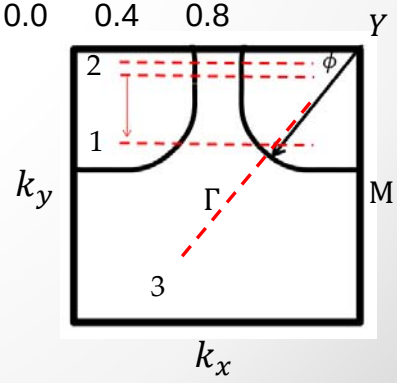
$$\epsilon_k = \epsilon_0 - 2\boldsymbol{t}\left[cos(k_x a) + cos\left(k_y a\right)\right] - 4t'\left[cos(k_x a)cos\left(k_y a\right)\right] - 2t''\left[cos(2k_x a) + cos\left(2k_y a\right)\right]$$

- Simulated with measured tight binding parameters of CLBLCO

Raw Data

CLBLCO $x = 0.1$

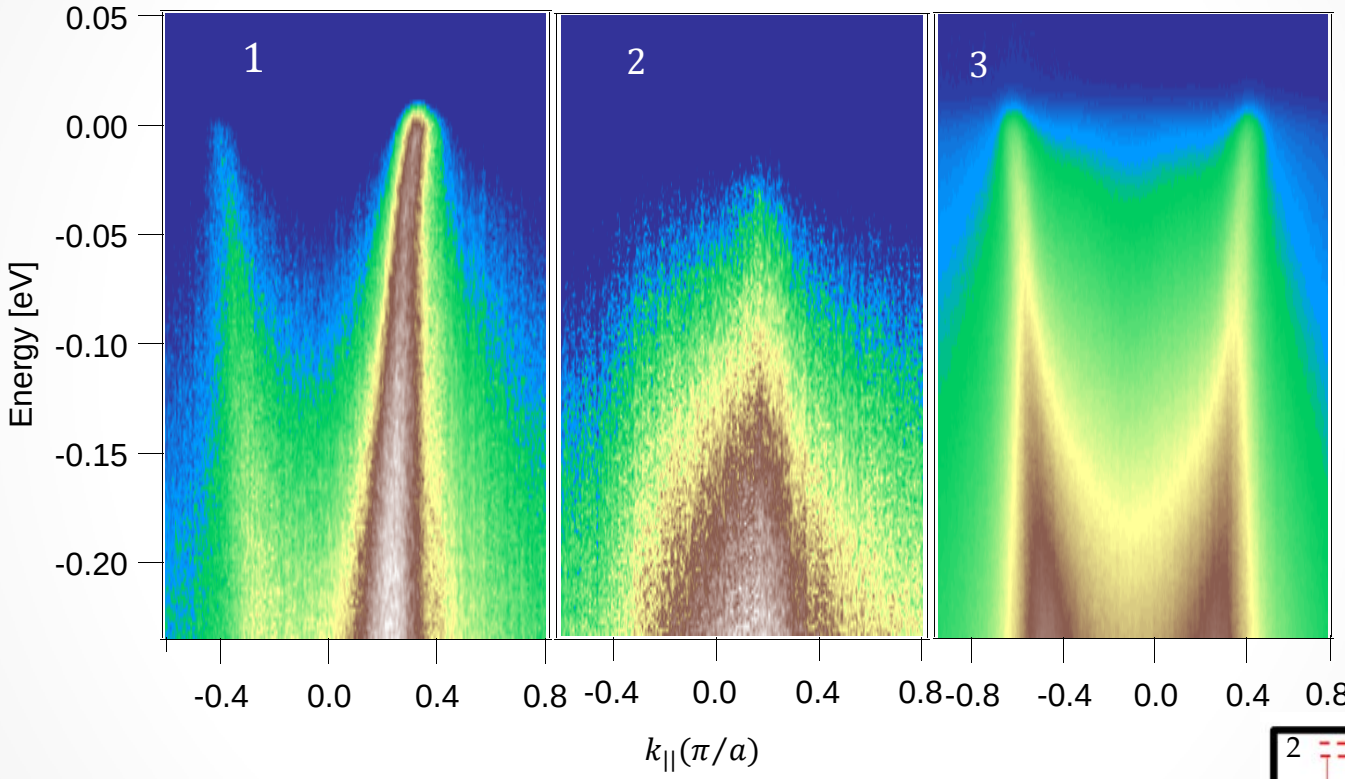


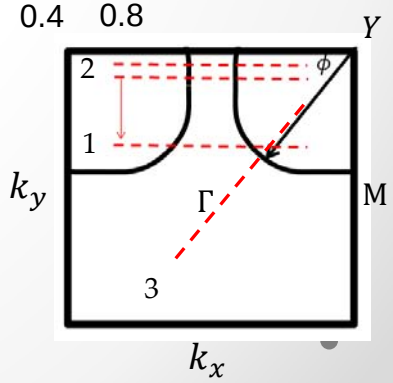


Measured in SLS, PSI, Switzerland

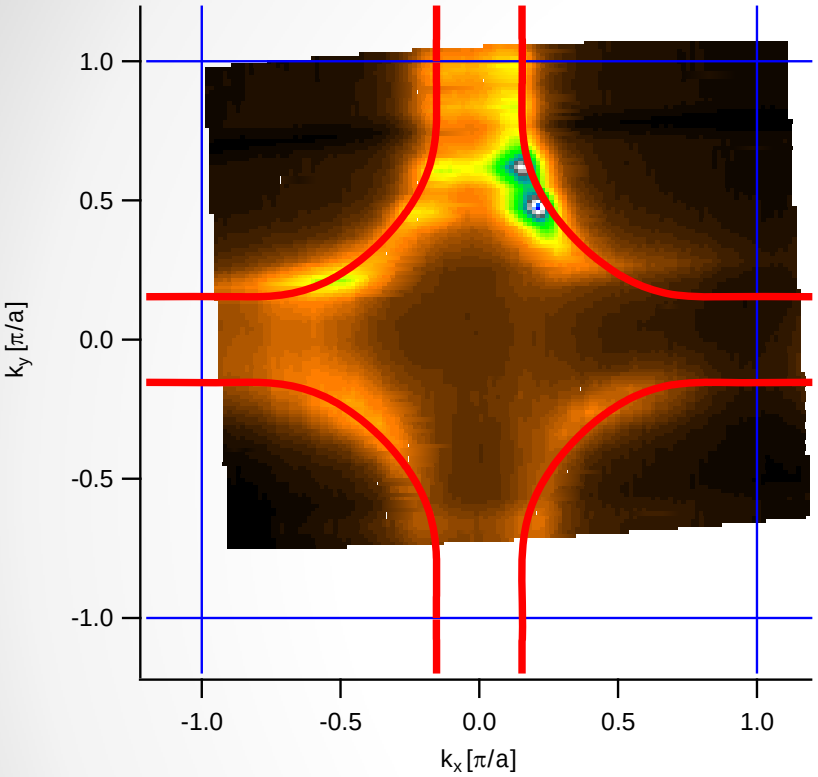
Raw Data

CLBLCO $x = 0.4$

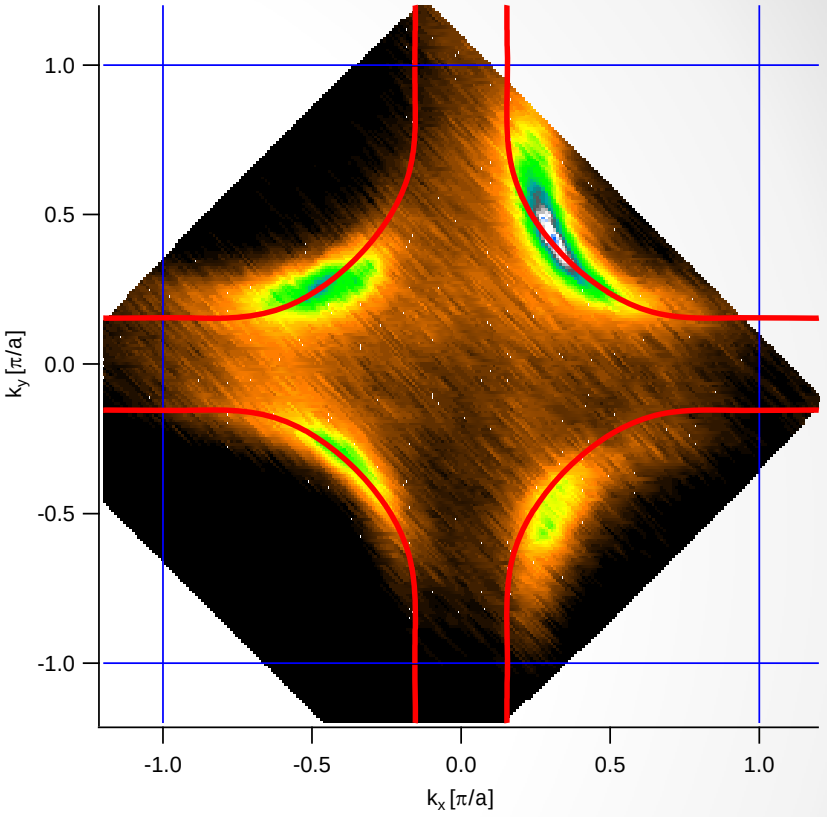




The Fermi Surface of CLBLCO



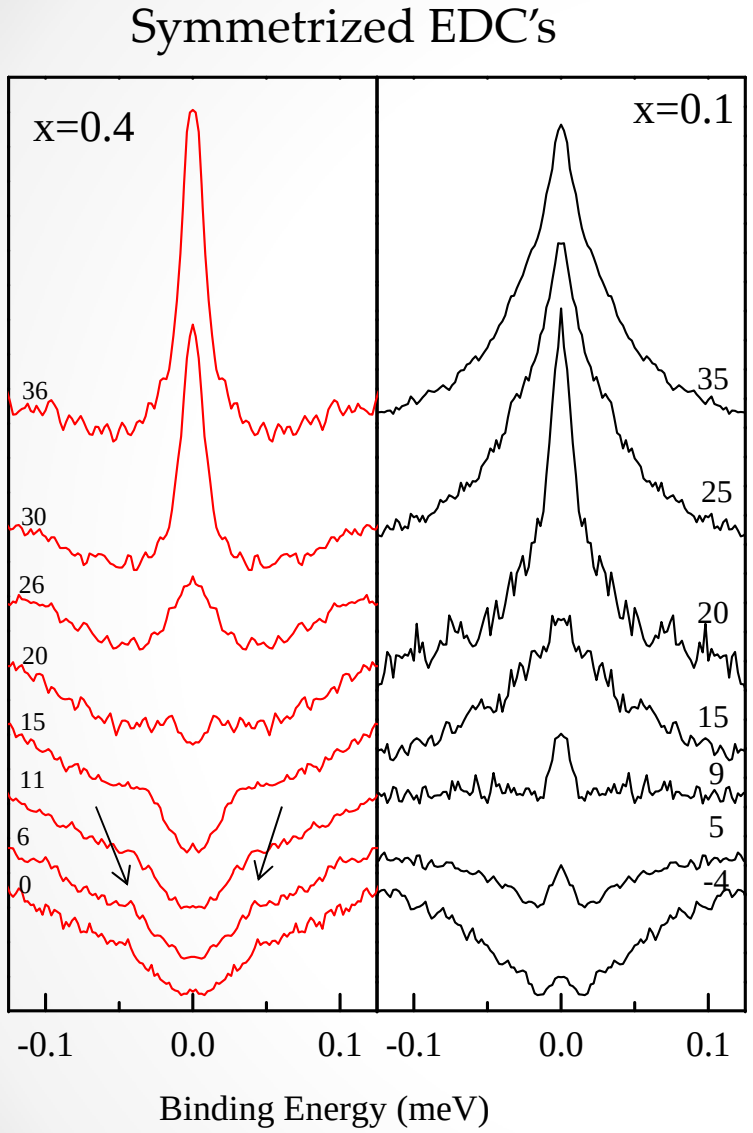
X=0.1

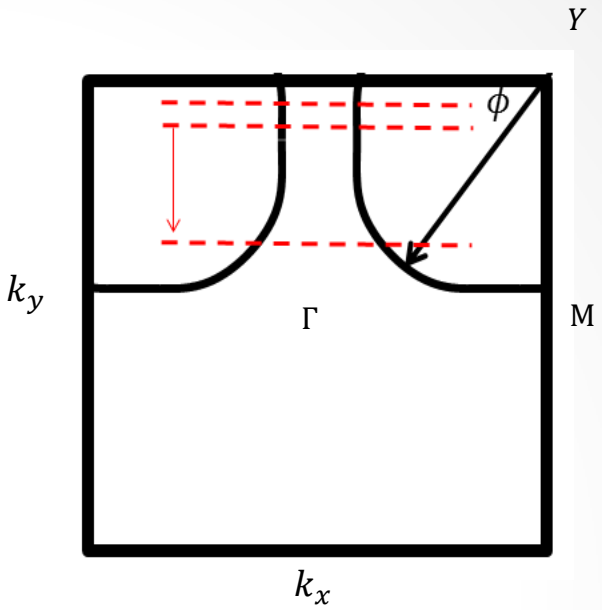


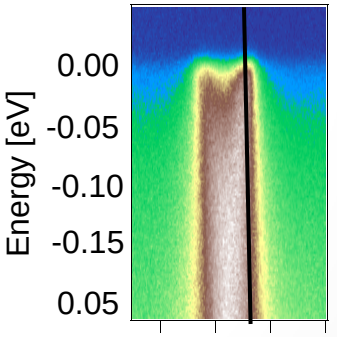
X=0.4

The doping of the surface appears independent of the preparation doping of the bulk crystal and is the same for both families.

The gap of CLBLCO



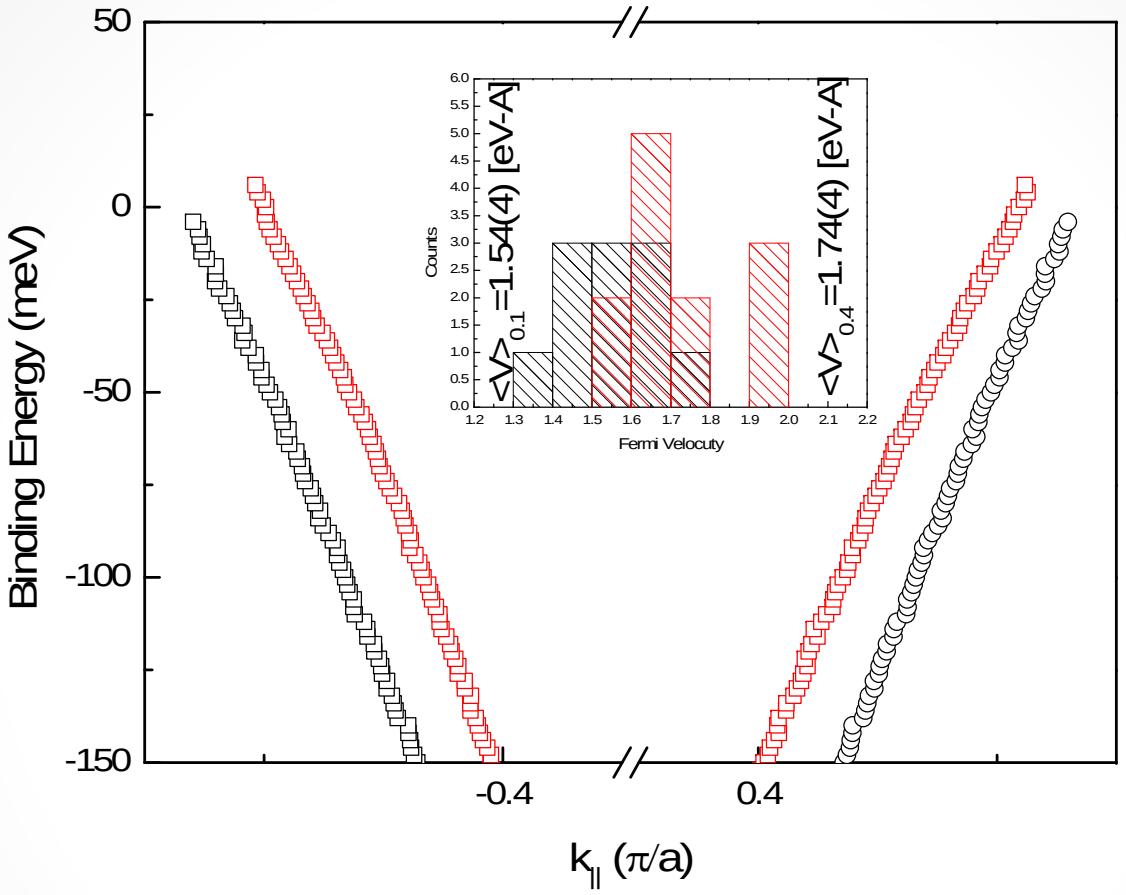


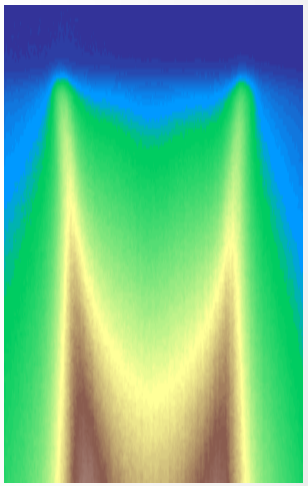


$$I(k,\omega) \propto \mathrm{A}(k,\omega) f(\omega)$$
$$f(\omega) = 1 - f(-\omega)$$

- for x=0.4 the gap is 40meV (similar to YBCO with same doping) and for x=0.1 below the resolution of 20meV

Fermi velocity in CLBLCO





The larger Fermi velocity in x=0.4 is in accordance with a larger hopping integral t, (or superexchange J~t^2) in this family, as was previously determined indirectly by muSR.

Summary

- We are able grow large crystals of CLBLCO.
- We obtained the first ever ARPES from a CLBLCO crystal
- We measured the difference in the Fermi velocity between CLBLCO families in accordance with a larger hopping .
- We measured a difference in Gap between CLBLCO families
- The larger gap in x=0.4 suggests that the anti-nodal gap and T_c are correlated. This conclusion could not be obtained from other materials.

Future Plans

- We plan to improve the ARPES data, and provide more evidence on the difference between the other two CLBLCO families (x=0.2, x=0.3).
- We intend to measure the full Spin-wave dispersion relation with neutron scattering and extract the super-exchange constant J.