Electron momentum densities in high-\(T_c\) superconductors

High-\(T_c\) superconductors were discovered ten years ago and since then have been intensively studied. However, a theory explaining the fundamental mechanisms of high-\(T_c\) superconductivity has yet to be formulated.

One of the keys to this step is understanding normal-state (above the critical temperature) properties of these materials. Unusual behaviour in the normal state reflects strong structural anisotropies.

Other characteristic properties (for example the linear behaviour of the d.c. resistivity and a temperature dependent Hall coefficient) indicate that it may not be possible to describe this state as a Fermi liquid.

Many theories have been put forward, some generalising the concept of the Fermi liquid, while others attempt to describe coulombic interactions and possible highly correlated behaviour using Hubbard or t-J models.

In this context, it is important to study the electron momentum density of these materials, which, when compared to predictions of theoretical models, can give an indication of their correctness or applicability. Detecting the energy of inelastically scattered photons at a fixed angle in back-scattering geometry from a mono-energetic beam incident on the sample, gives access to the Compton profile. This is a projection onto one dimension of the true electron momentum density.

\(\text{YBa}_2\text{Cu}_3\text{O}_7\) (YBCO) belongs to the category of high-\(T_c\) superconductors with \(T_c \sim 92\) K and other members of this class are formed when most rare-earth elements are substituted for yttrium. An exception is praseodymium: \(\text{PrBa}_2\text{Cu}_3\text{O}_7\) (PrBCO) is an insulator macroscopically, even though isostructural with YBCO (lately there have been reports of superconducting PrBCO crystals but those used in this experiment were insulators). This is one reason to study both materials since understanding the absence of superconductivity in PrBCO may lead to an insight into high-\(T_c\) superconductivity.

In this experiment we measured the difference of profiles between two crystallographic directions for both samples (100/010 - 110, the samples were twinned), and compared it to the theoretical prediction. The incident energy, 60 keV, was enough to provide a reasonable signal from these highly temperature superconductors.
absorbing materials. The scanning spectrometer used at beamline ID15B is designed such that the detector has a narrow receiving slit so as to minimise background. This is crucial for these samples as the background is very high due to Y, Pr and Ba fluorescence. High quality samples are small in size, and we used a stacking arrangement with three crystals mounted in a configuration where the full beam size, 0.2 mm x 6 mm, could be used, optimising the count rate.

**Figure 43** shows the results of the measurement. The theoretical prediction is from a FLAPW calculation and has been scaled to the typical variation in the data. It reproduces most features in the measured difference profile for YBCO, the biggest deviations being at low momentum. Quantitative comparisons will be made later when a more complete calculation with the full core component is available.

There is also a remarkable difference between the PrBCO and YBCO data. This is an important fact because calculated band structures for these are very similar. The unit cell in both can be thought of as containing two different structural entities composed of copper and oxygen atoms: one-dimensional chains and two-dimensional planes. Earlier Cu-O chain momentum density measurements in these two materials using optical reflectivity and positron annihilation have shown very similar behaviour in YBCO and PrBCO. The difference seen now probably originates in the Cu-O planes which are also the seat of superconductivity.

Further efforts at ID15B will centre around trying to pinpoint the origin of these differences and performing other experiments to check the veracity of theoretical predictions concerning these materials.

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A. Shukla (a), V. Honkimäki (a), T. Buslaps (a), P. Suortti (a), A. Erb (b), A.A. Manuel (b), D. Vasumathi (b), B. Barbiellini (c), to be published.

(a) ESRF
(b) DPMC, University of Geneva (Switzerland)
(c) Solid State Group, University of California, Los Angeles (USA)

**High frequency dynamics of glass forming liquids at the glass transition**

The study of the high frequency density fluctuations in glass-forming liquids has received great attention, and one of its aims is to improve our understanding of the microscopic mechanisms responsible for the liquid-glass transition. Whether the liquid-glass transition must be considered as a classical phase transition is, in fact, still a highly-debated topic.

For example, the glass transition temperature $T_g$, associated with the macroscopic structural arrest, cannot be considered as a critical transition temperature because certain quantities of the system show an anomalous behaviour at temperatures different from $T_g$: among others, the time scale dependence of the structural relaxations and the ergodicity of the system. Similarly, an order parameter in the classical sense has not yet been identified and there are properties that depend on the cooling rate. These issues have been the object of many theoretical models, extending from thermodynamic descriptions of the transition [Kivelson et al.], to pure dynamical approaches as the mode coupling theory (MCT) [Bengtzelius et al.].