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The low-lying electronic structure of the superconducting cuprates:

an ARPES view from Dresden

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Collaboration

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Samples:

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Photons:

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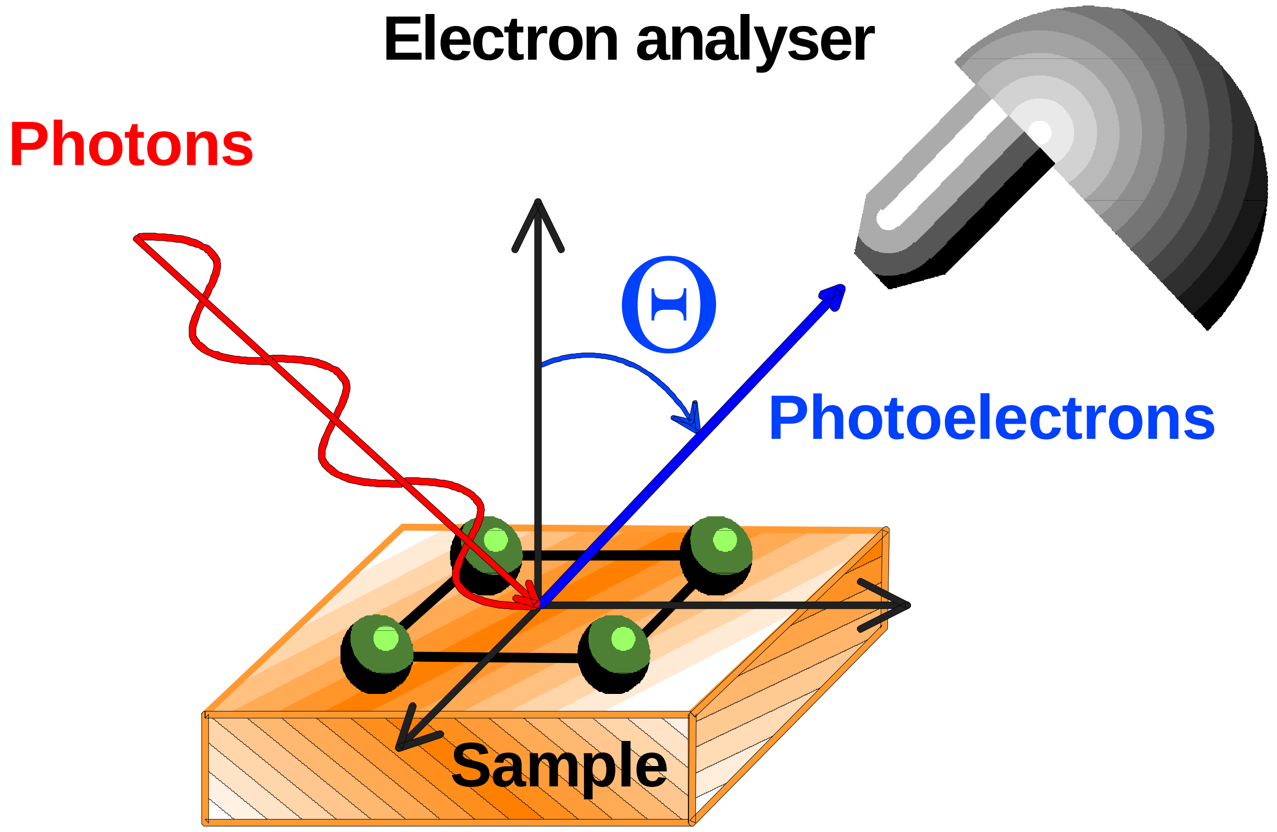
Stefano Turchini

ARPES

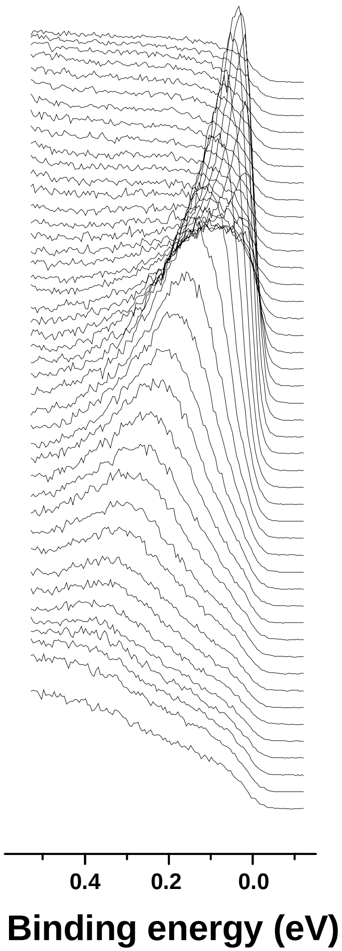
- ARPES is the most direct way to explore the electronic structure of solids, in particular, the superconducting cuprates, which are key representative of the strongly correlated electron systems.
- Light source + manipulator + analyser = **k**ω-space explorer. Many of these are currently in use over the world.

Photoemission experiment

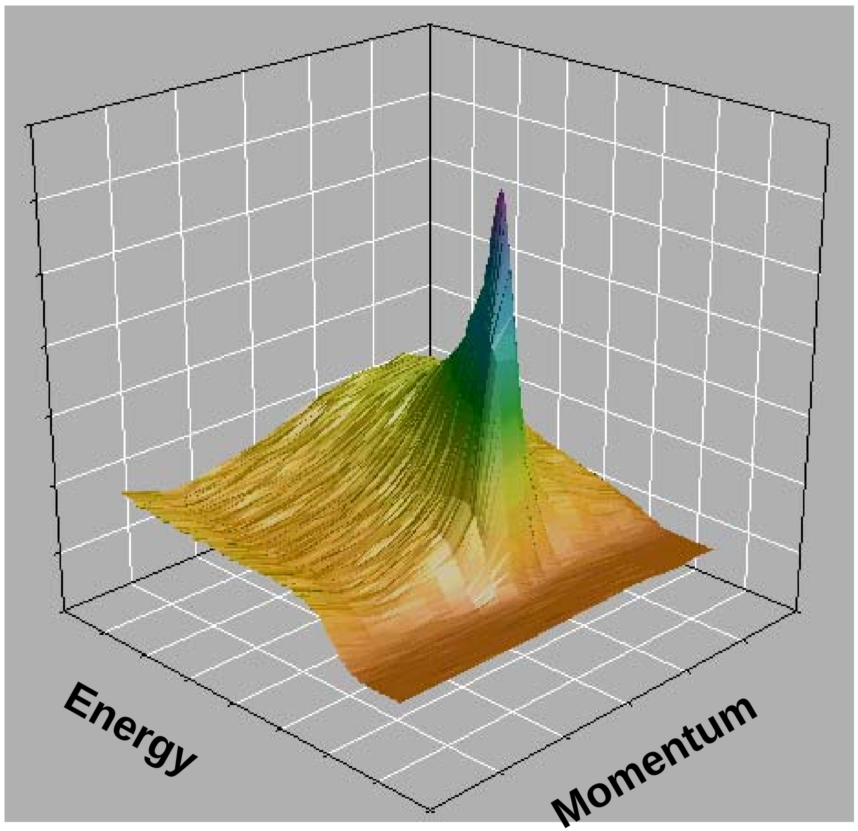


Photoemission data

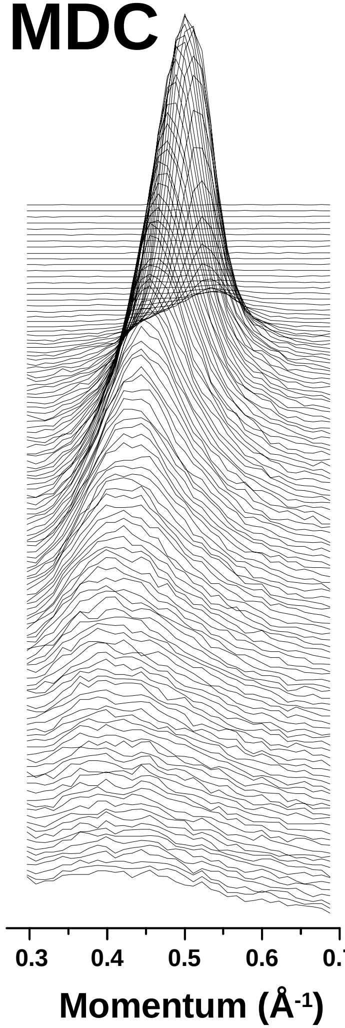
EDC

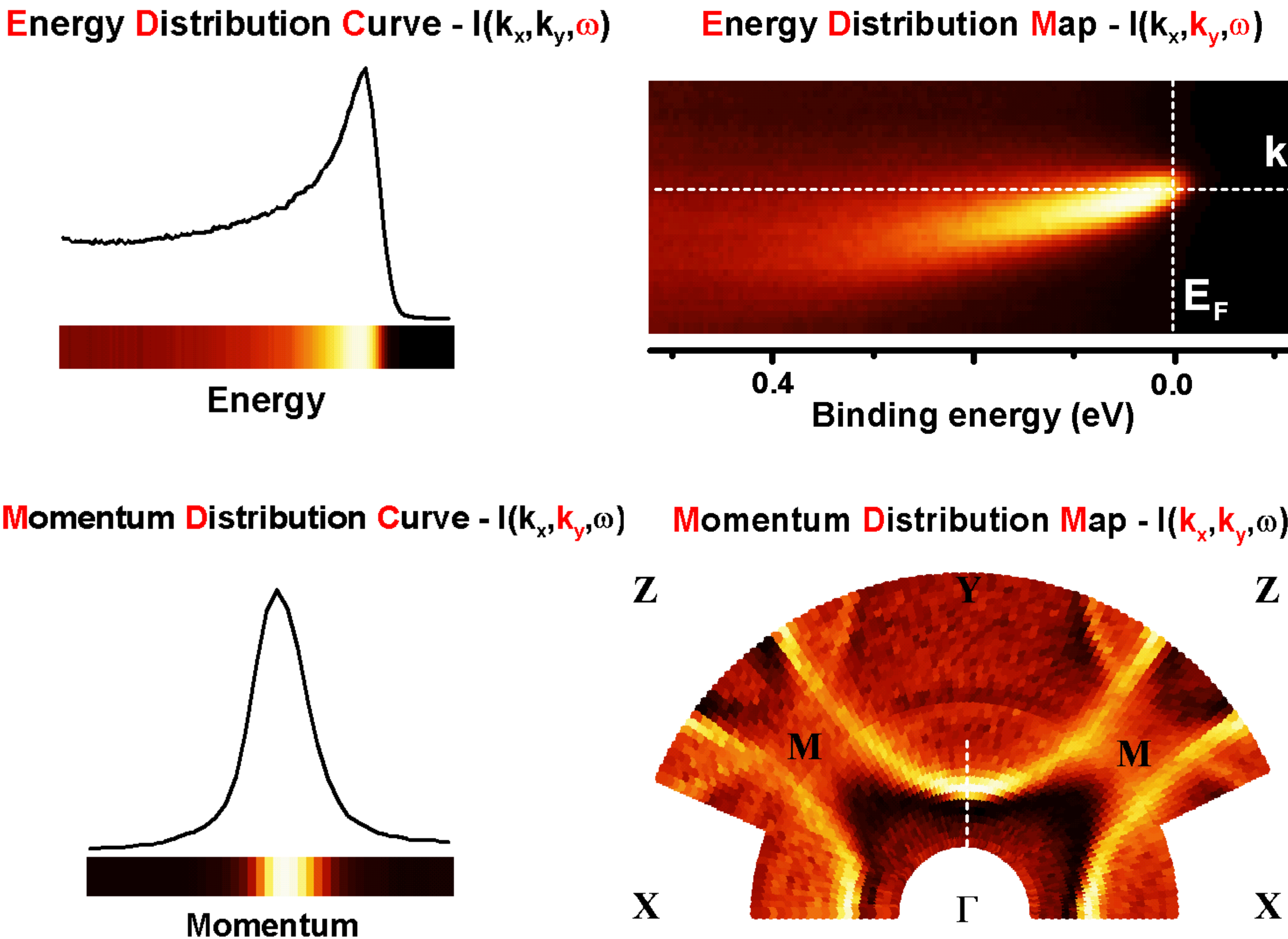


$I(k,\omega)$



MDC

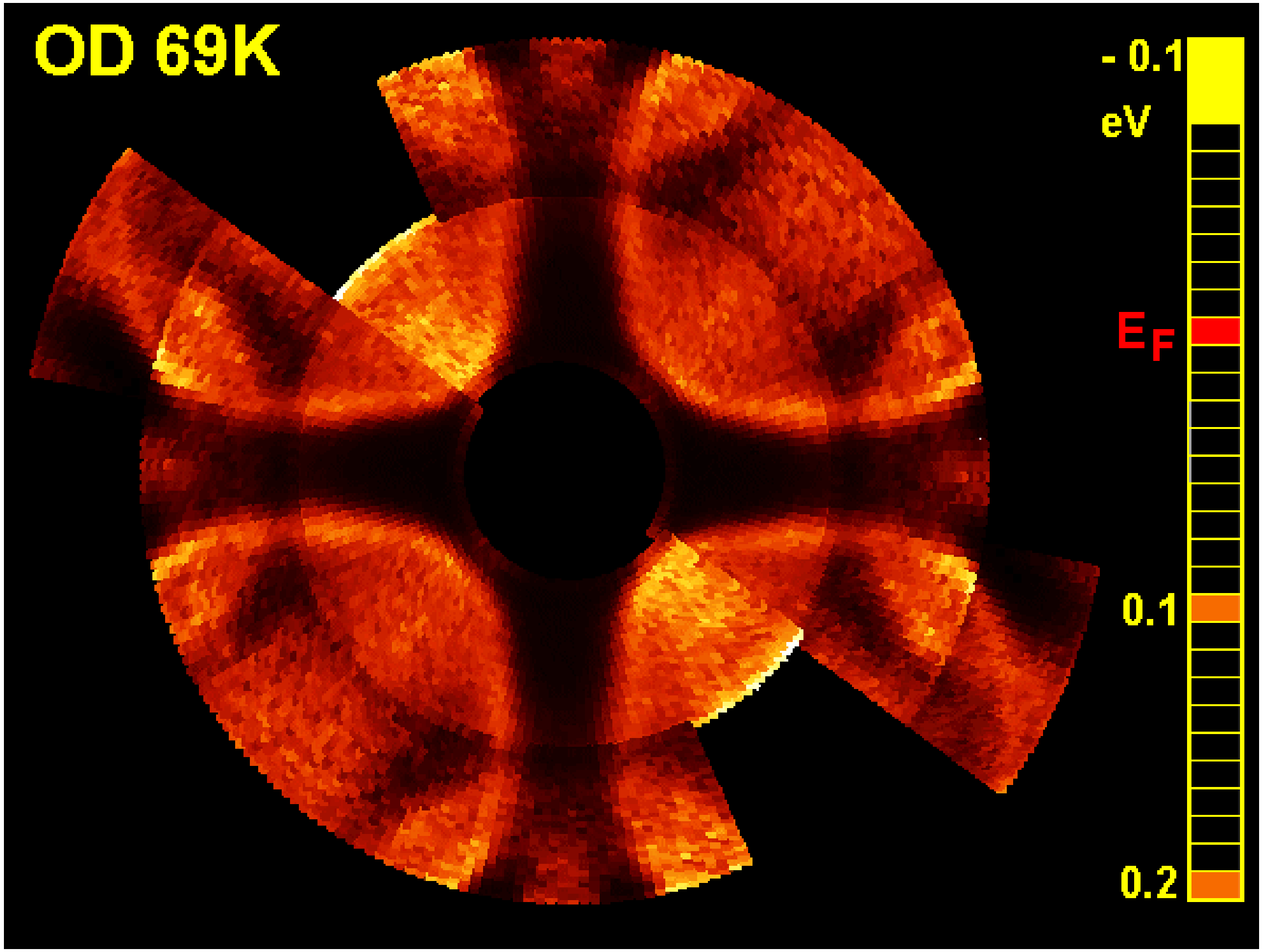



Energy Distribution Curve - I(kx,ky,ω)
Energy
Energy Distribution Map - I(kx,ky,ω)
kF
EF
0.4
0.0
Binding energy (eV)
Momentum Distribution Curve - I(kx,ky,ω)
Momentum
Momentum Distribution Map - I(kx,ky,ω)
Z
Y
Z
M
M
X
Γ
X

ARPES in IFW

- The main experimental problem which stays between us and our understanding what's going on in the cuprates is the lifetime of the sample.
- The main advantage of the IFW group is in precise mapping technique. This comes from combination of SES electron analyzers, the manipulator (3 axis sample rotation system), and light sources (He-lamp, BESSY, ELETTRA).

Momentum Distribution Map



Why maps are so important

- Precise **k**-location through the map correction procedure (e.g., to determine the gaps correctly it is crucial to know an exact **k**-position of each spectra).
- Superstructure influence can be seen on maps (e.g. M-region, N-region).
- Matrix elements (FS topology, bonding-antibonding).

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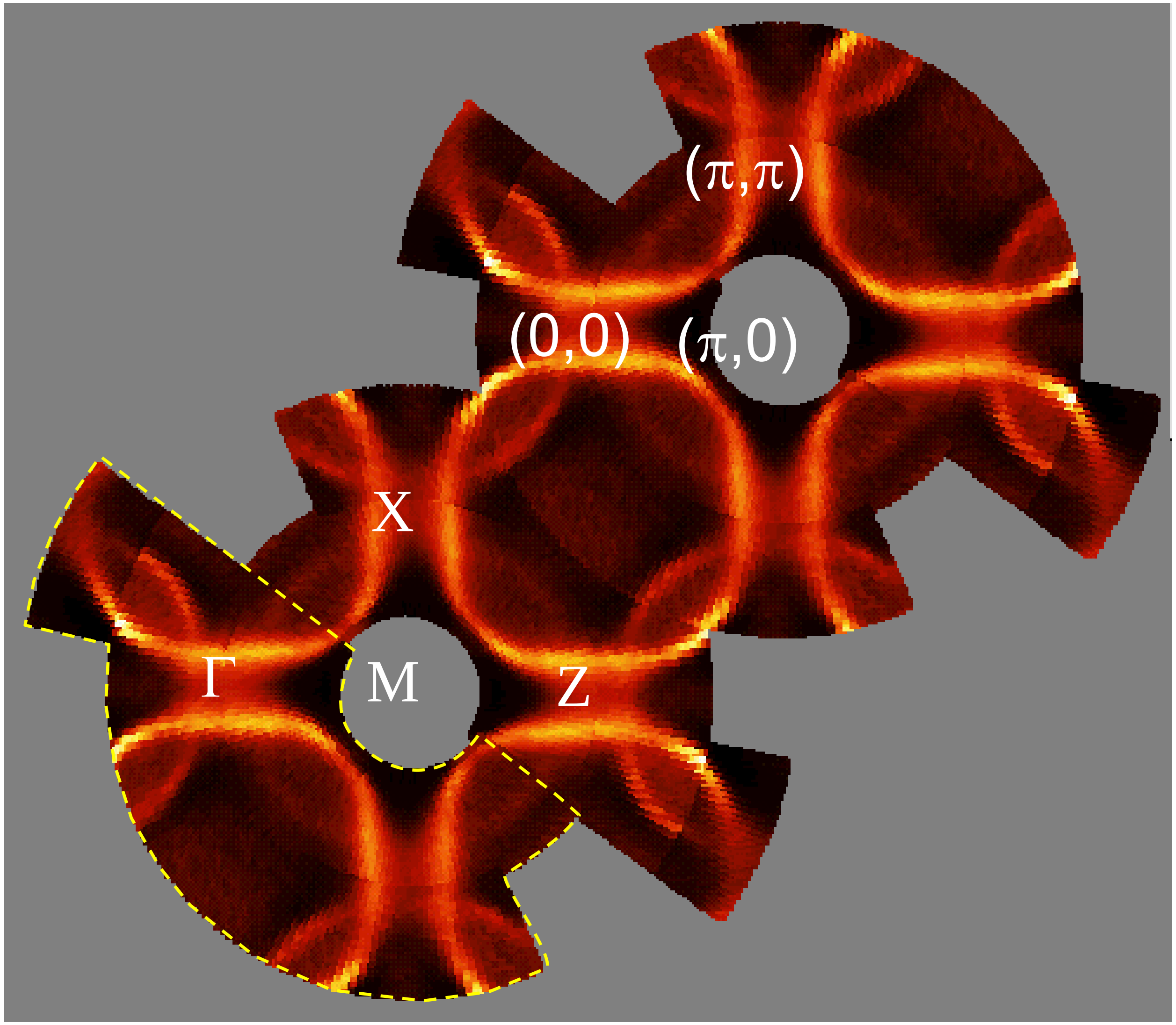
Fermi surface map



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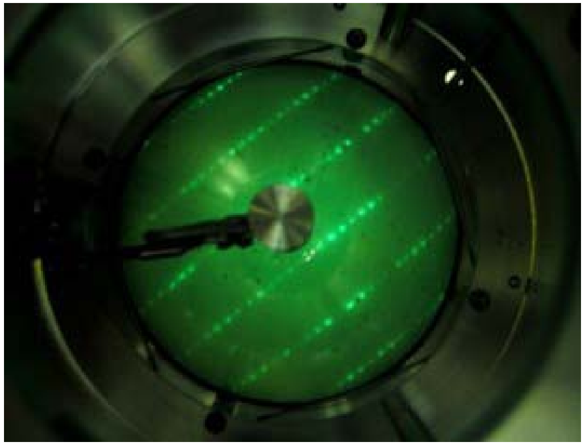
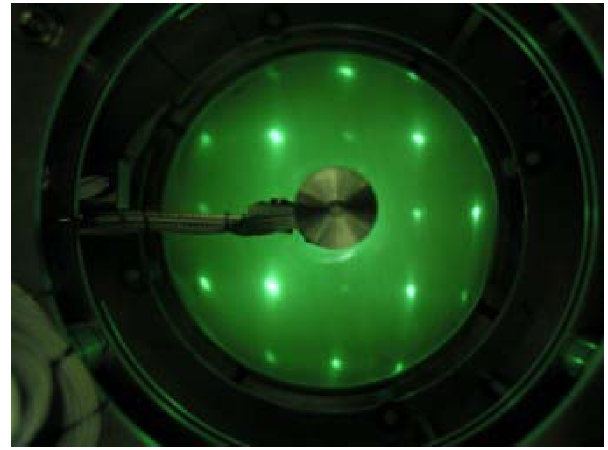
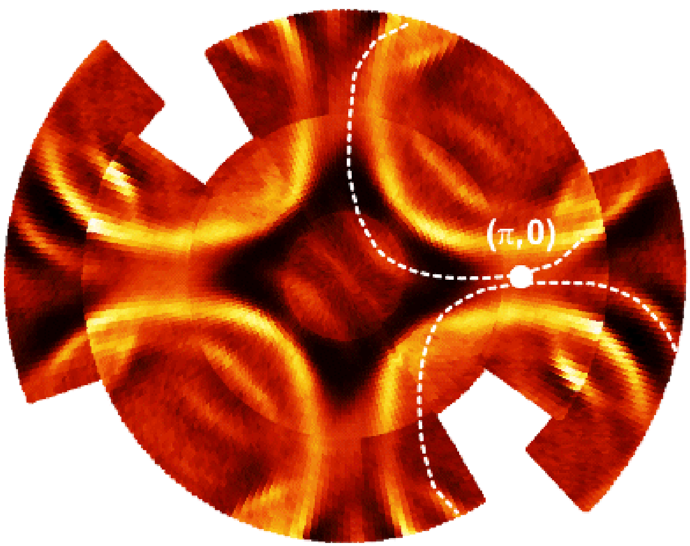
Pb or not Pb

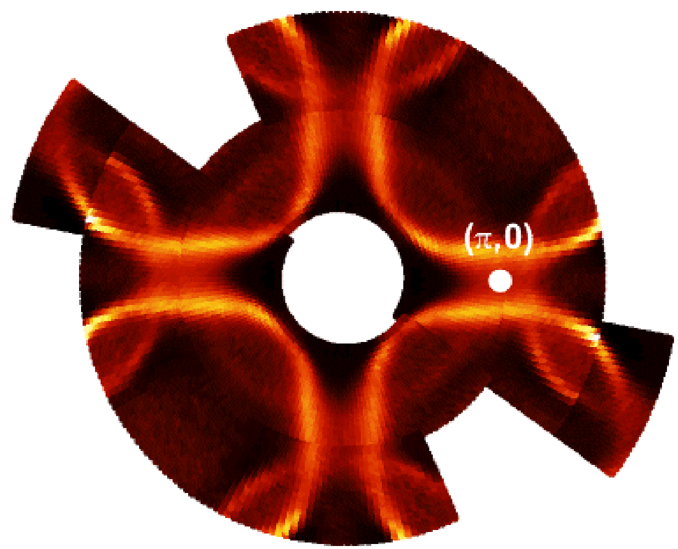




Bi2212

Pb-Bi2212





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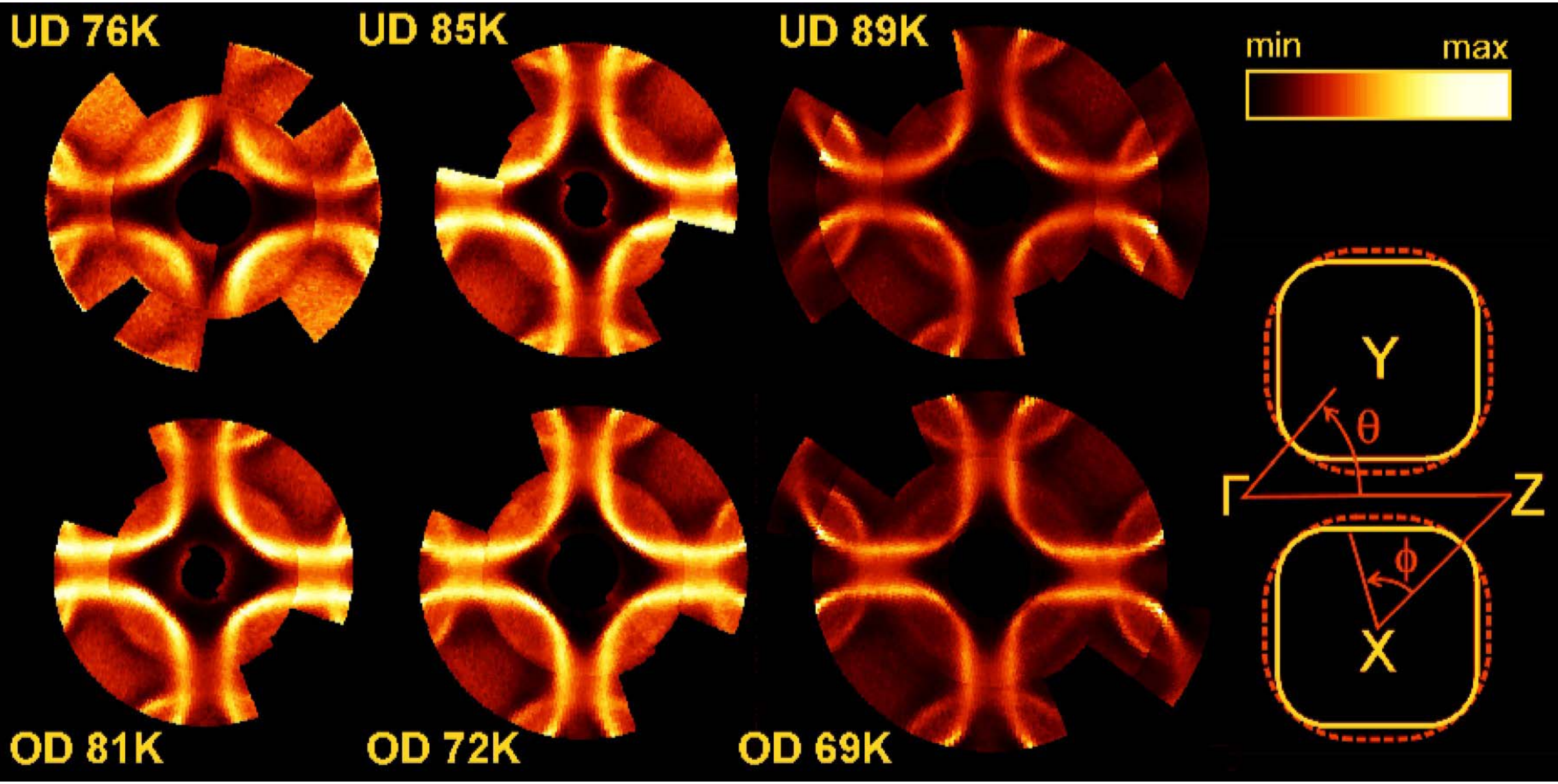
New century ARPES with the bilayer splitting: what should be reconsidered

- Peak-dip-hump (PDH) based teories.
- Electronic structure in general, position of the saddle point in particular. The question about BiO pockets can be revived.
- EDC width as an "evidence for absence of quasiparticles" in the anti-node, as well as actual dispersion, kinks, etc. in this region.
- The Gaps.

Doping dependence of Fermi Surface in Bi(Pb)-2212



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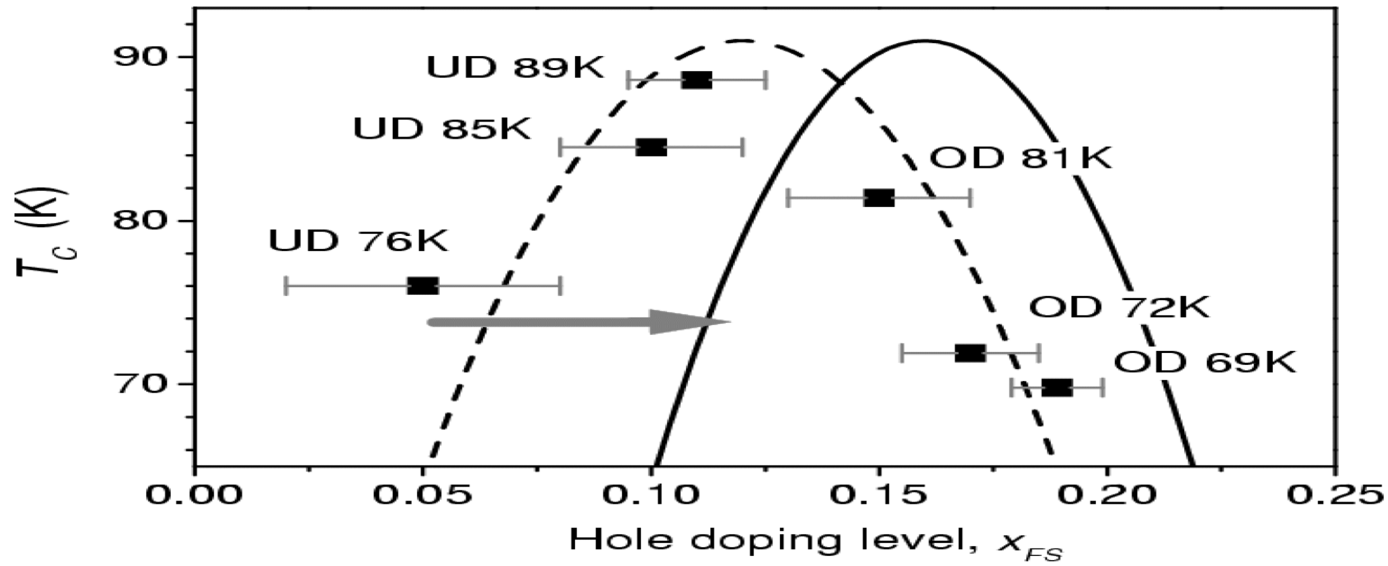
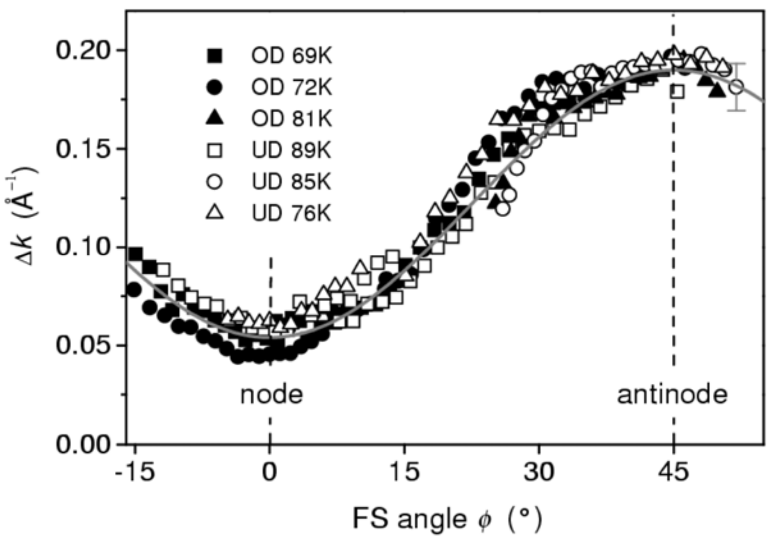
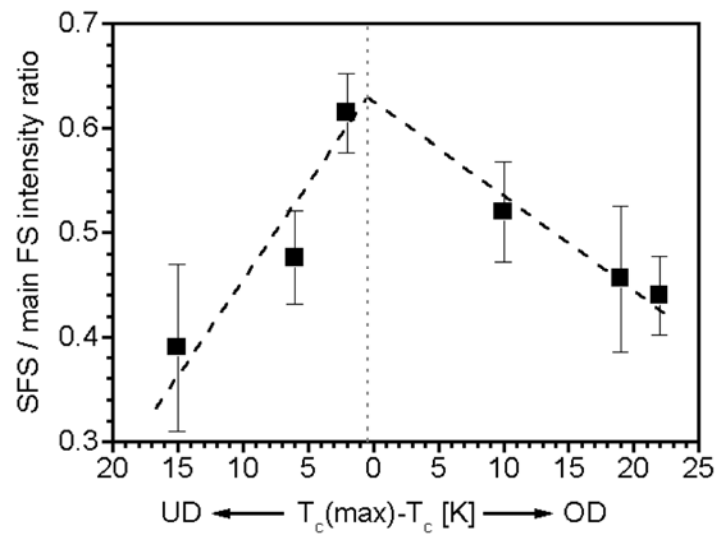
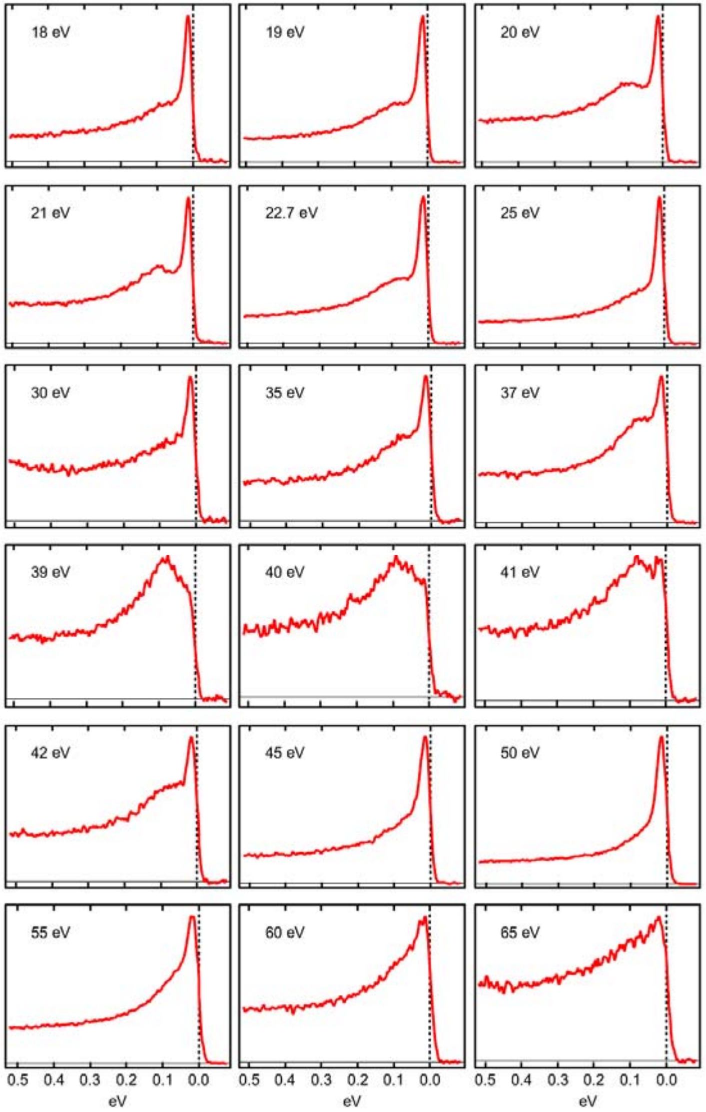




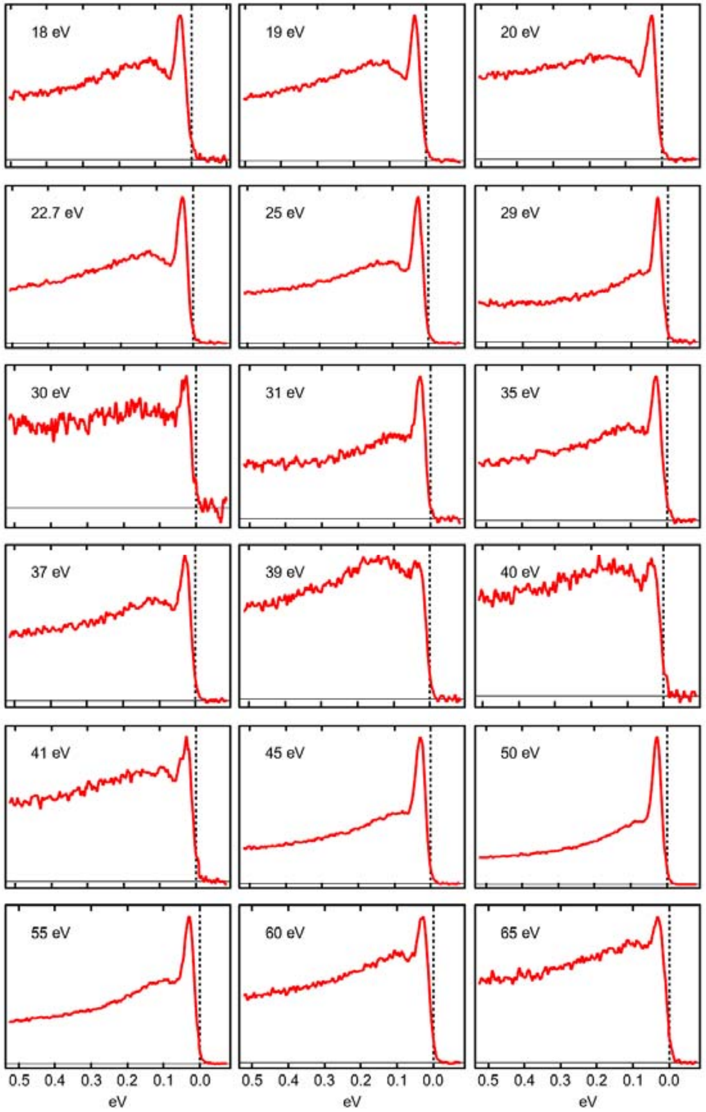


Peak-dip-hump lineshape

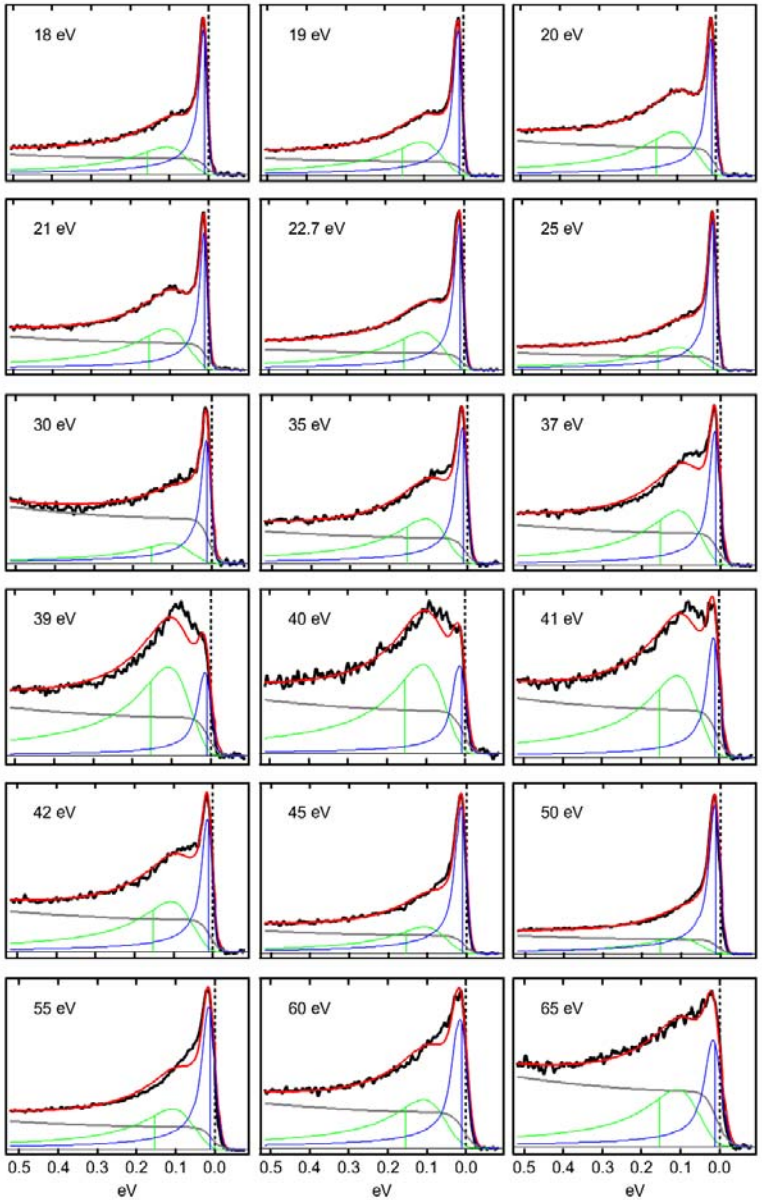
OD

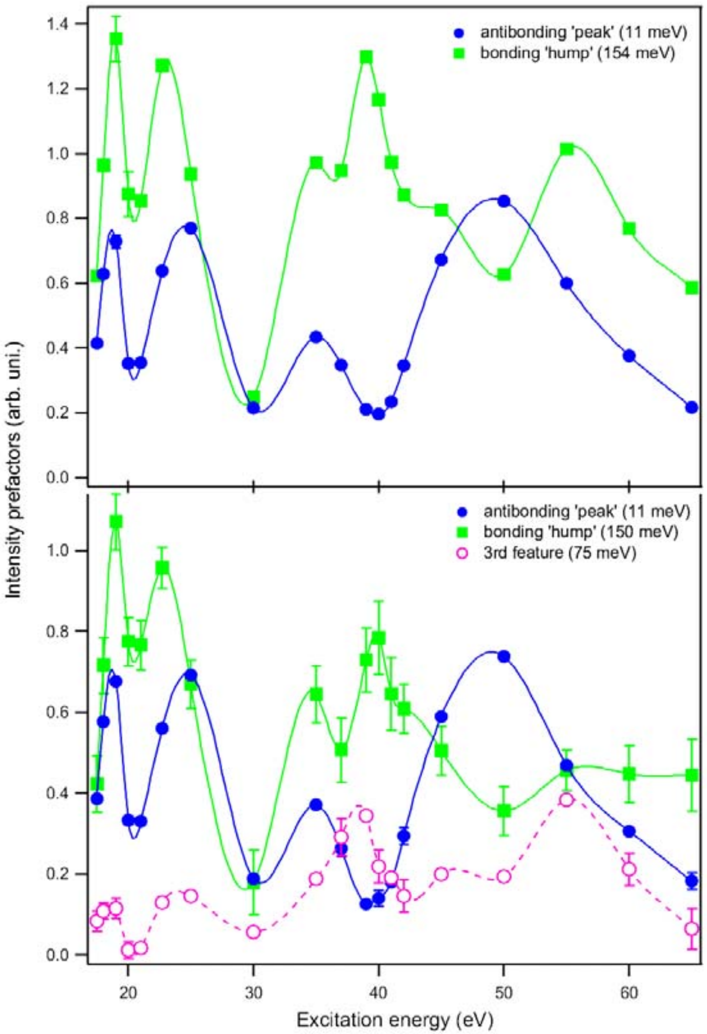


UD



Energy dependence of PDH for OD Bi(Pb)-2212





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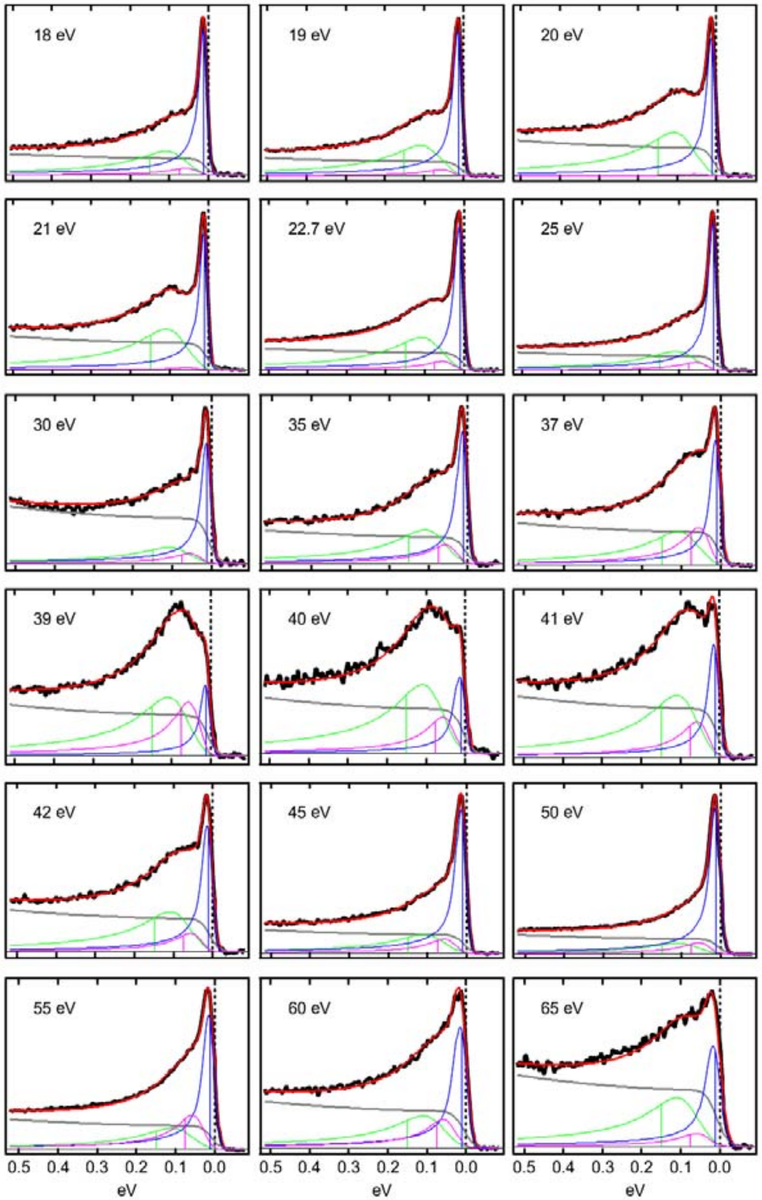
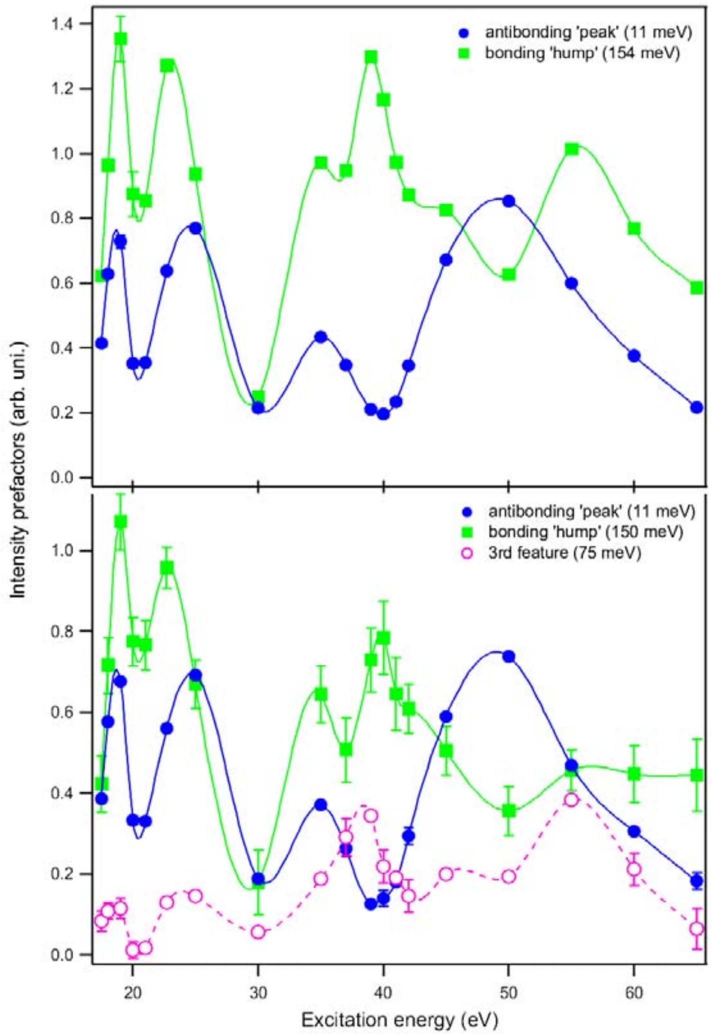




Self-energy: $(\pi,0)$ point

Fitting function

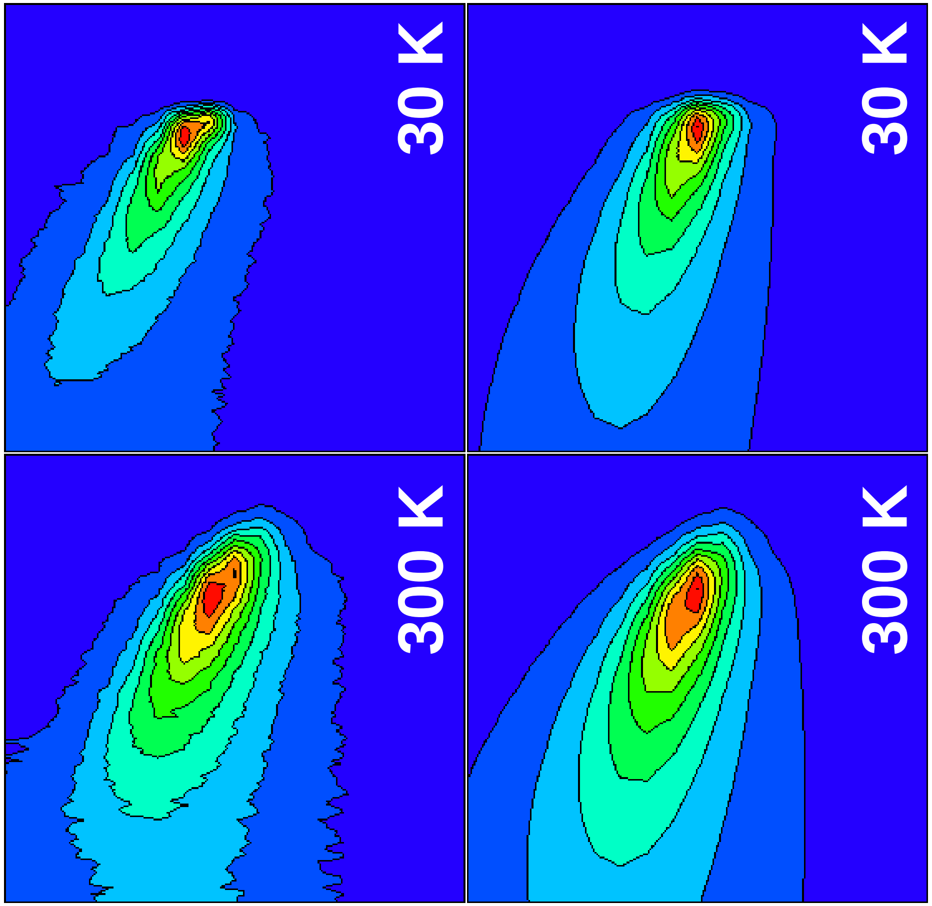
$$I(\omega,T,h\nu) \propto [(M_a(h\nu)A(\omega,\varepsilon_a,T) + M_b(h\nu) \times A(\omega,\varepsilon_b,T)) f(\omega,T)] \otimes R_\omega + B(\omega,T)$$

$$A(\omega,\varepsilon,T) \propto \frac{|\Sigma''(\omega,T)|}{(\omega-\varepsilon)^2 + \Sigma''(\omega,T)^2}$$

$$\Sigma''(\omega,T) = \sqrt{(\alpha\omega)^2 + (\beta T)^2}$$

OD69K $\alpha = 1.1 \pm 0.1, \quad \beta = 2$

Self-energy: nodal direction



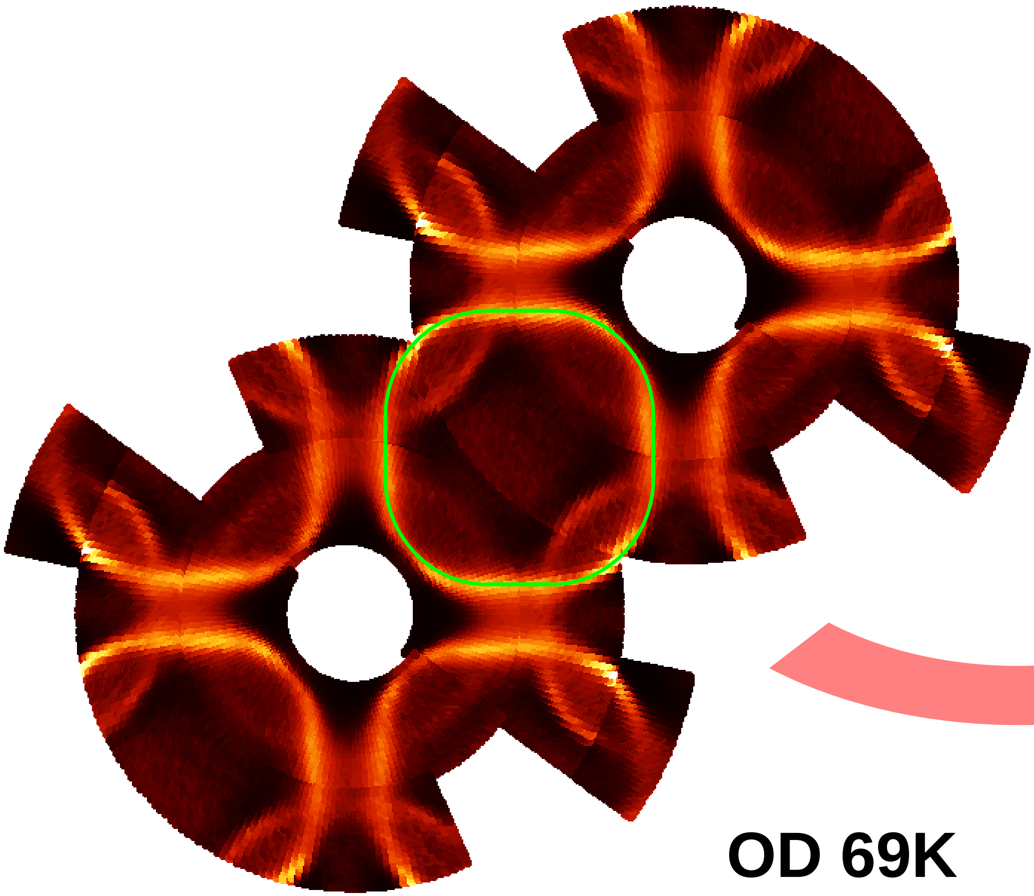
experiment   model

$$\Sigma''(\omega, T) =$$
$$= \sqrt{(\alpha\omega)^2 + (\beta T)^2}$$

$$\alpha = 1$$
$$\beta = 2$$

Tight binding fit

$$\varepsilon(k_x,k_y)=\Delta\varepsilon-2t(\cos k_x+\cos k_y)+4t'\cos k_x\cos k_y-2t''(\cos 2k_x+\cos 2k_y)$$

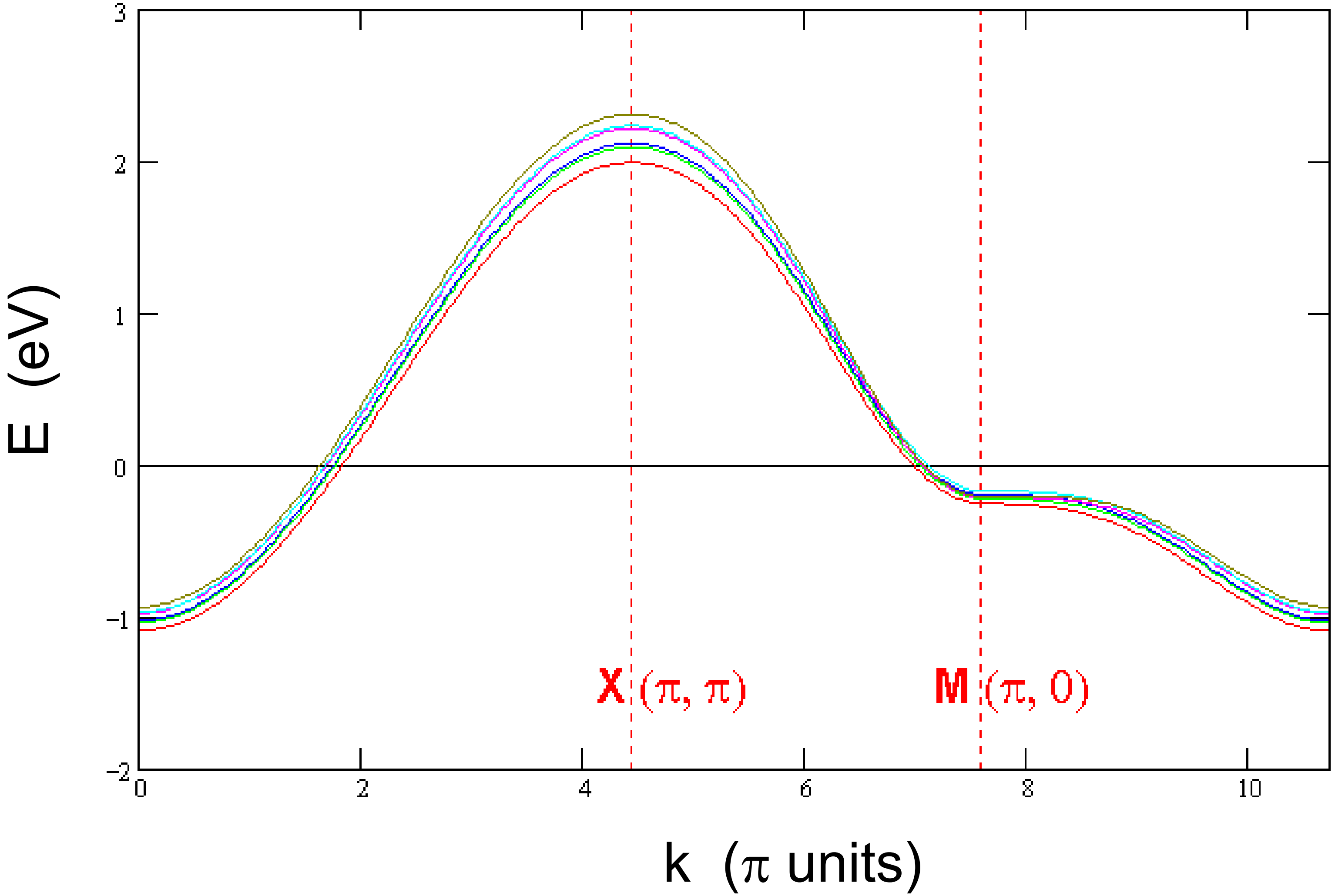


$$\Delta\varepsilon\approx 0.4\,\mathrm{eV}$$
$$t\approx 0.4\,\mathrm{eV}$$
$$t'\approx 0.1\,\mathrm{eV}$$
$$t''\approx 0.05\,\mathrm{eV}$$

OD 69K

Γ-X-M-Γ bare dispersion for bonding band:

from UD76K to OD69K



Bare dispersion for bonding band:
from UD76K to OD69K

Saddle point depth: $|E(\pi,0)| = 260 - 150$ meV

Γ point depth: $|E(0,0)| \sim 1$ eV

Band width: $E(\pi,\pi) - E(0,0) \sim 3$ eV

Fermi velocity

nodal: $v_{FN} \sim 4$ eVA

antinodal: $v_{FA} \sim 3$ eVA

Antibonding band and bilayer splitting

Saddle point depth: $|E(\pi,0)|$ =

10 meV (for OD)

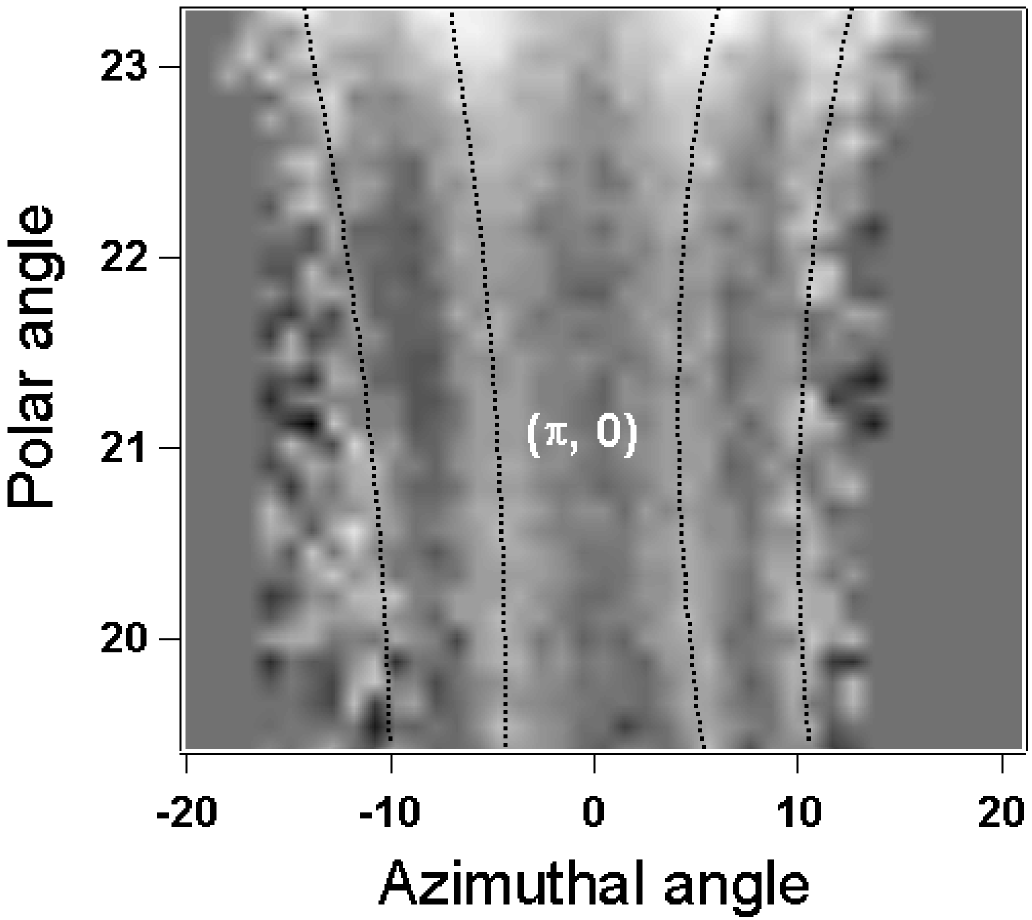
40 meV or 120 meV (for UD)

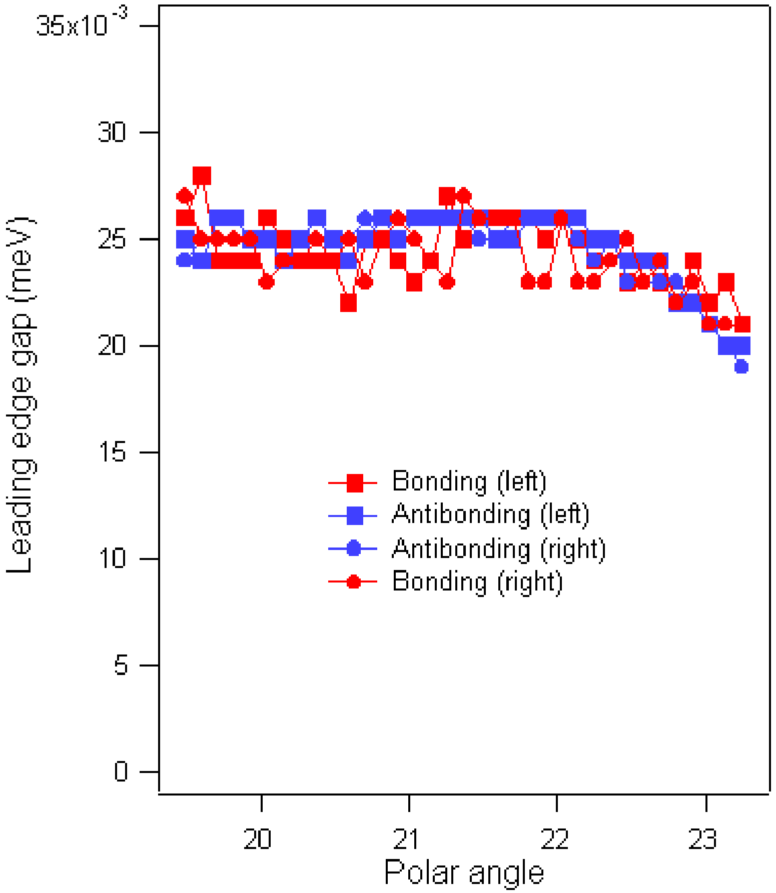
Bilayer splitting: $E_a(\pi,0) - E_b(\pi,0)$ =

140 meV (for OD)

220 meV or 140 meV (for UD)

Superconducting gap





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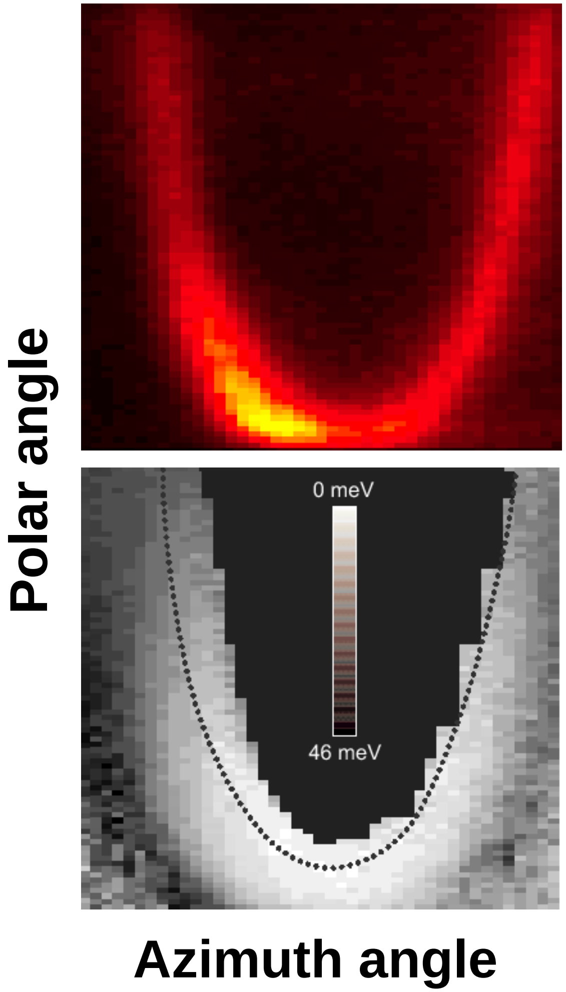

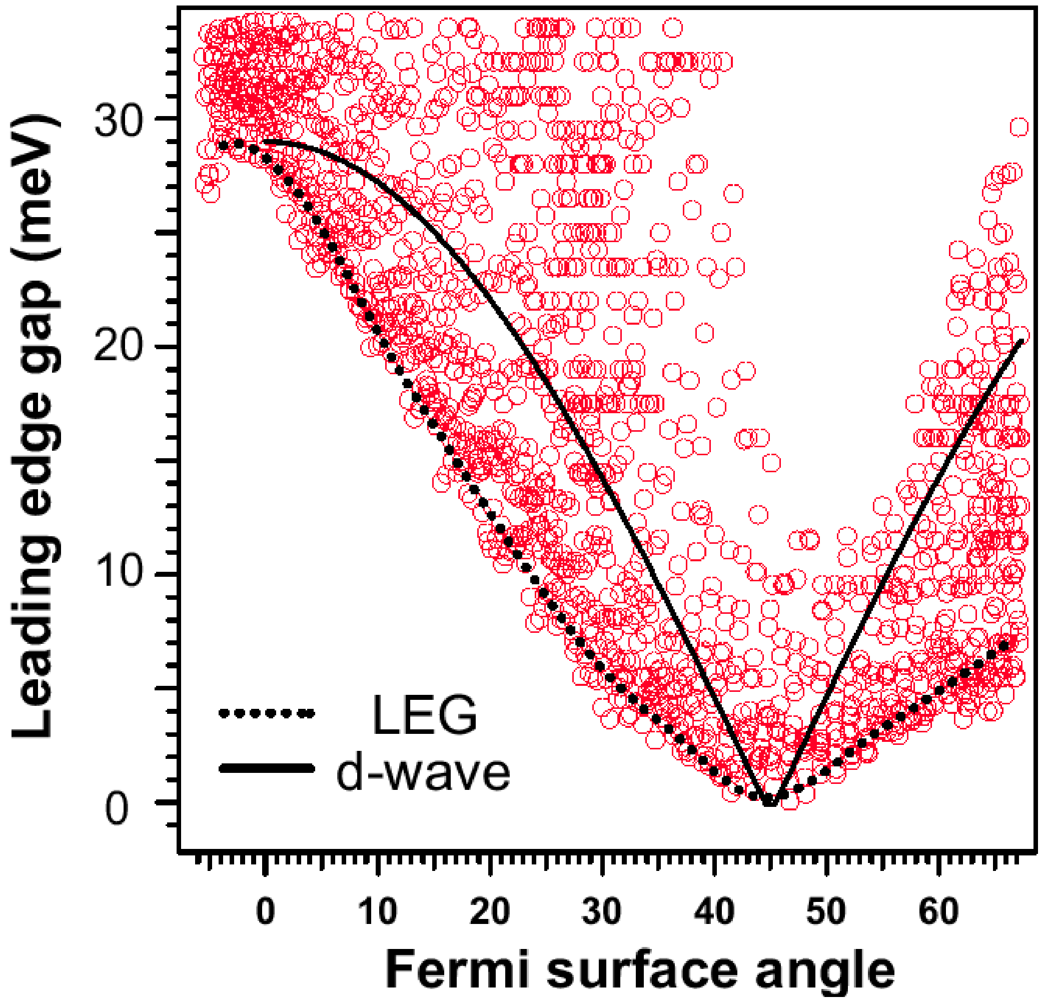

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