New finding in electronic properties of superconducting cuprates from nodal photoemission spectra

Alexander Kordyuk

IFW Dresden, Germany

IMP Kyiv, Ukraine

Thanks to:

Spectroscopy Group IFF, IFW Dresden

Sergey Borisenko, Timur Kim, Andreas Koitzsch,
Roland Hübel, Martin Knupfer, Jörg Fink

Experimental collaboration, single crystals

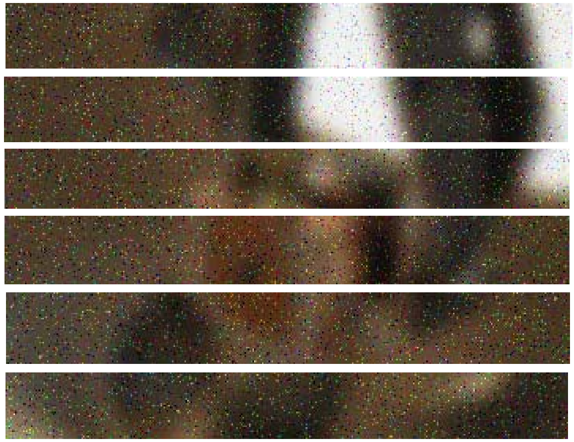
Rolf Follath	BESSY Berlin
Helmut Berger	EPFL Lausanne
Chengtian Lin, Bernhard Keimer	MPI Stuttgart
S. Ono, Yoichi Ando	CRIEPI Tokyo

Band structure calculations

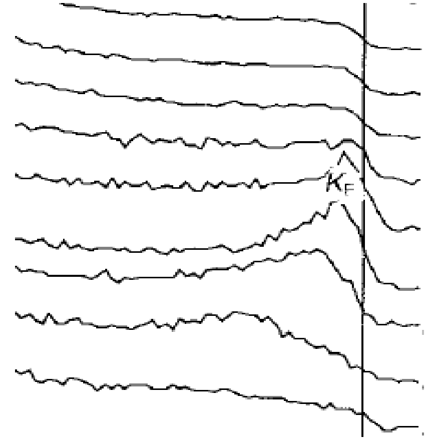
Alexander Yaresko	MPI-PKS Dresden
Stefan-Ludwig Drechsler	IFW Dresden

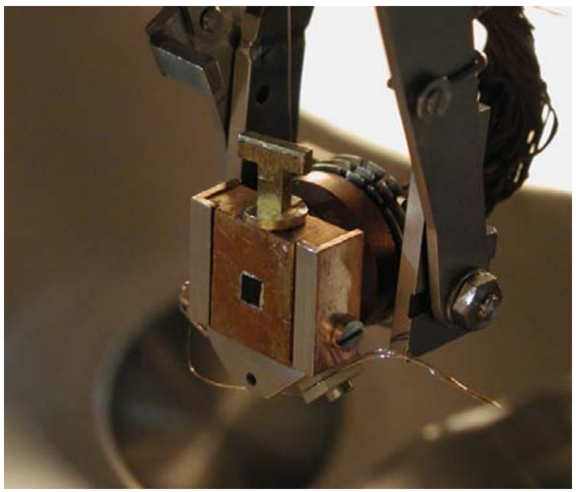
Navigation

- Introduction to ARPES
- The advantages of our group
- Electronic band structure
- Antinodal region
- Nodal region

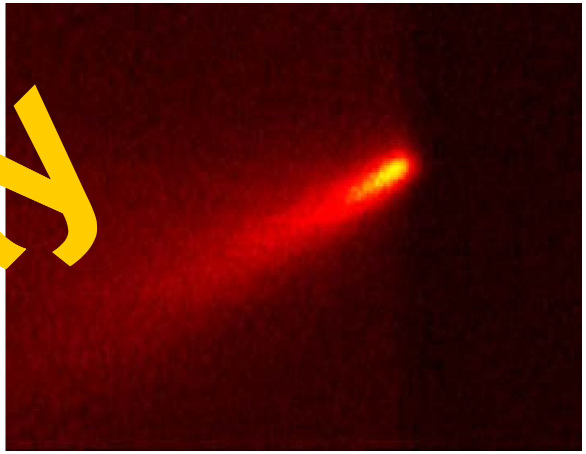


Last century ARPES

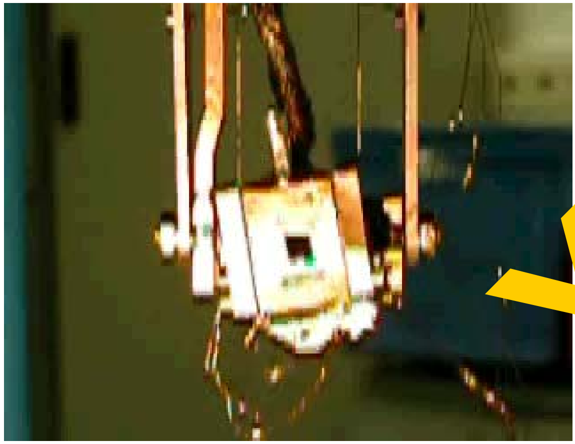




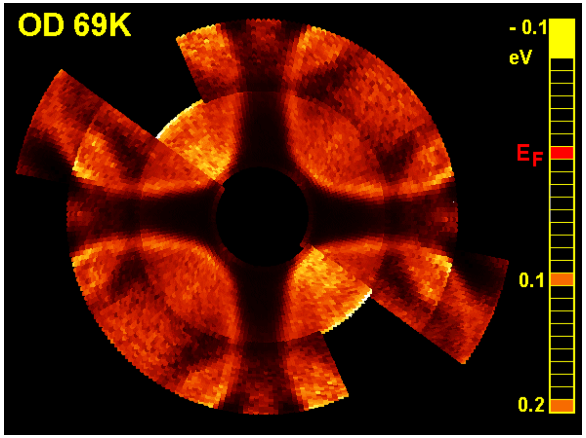
Today



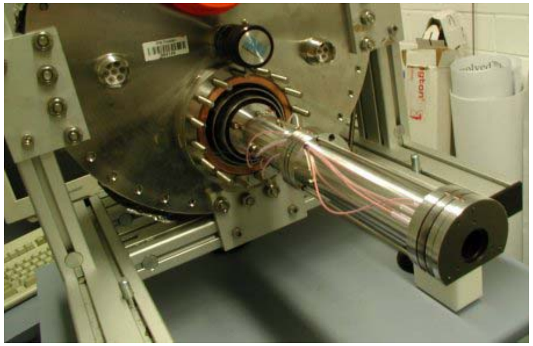
Yesterday



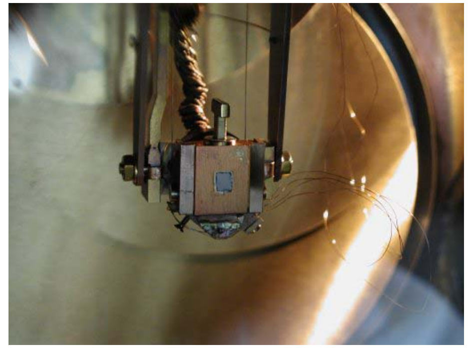
Today in Dresden



(k,ω)-space explorer today

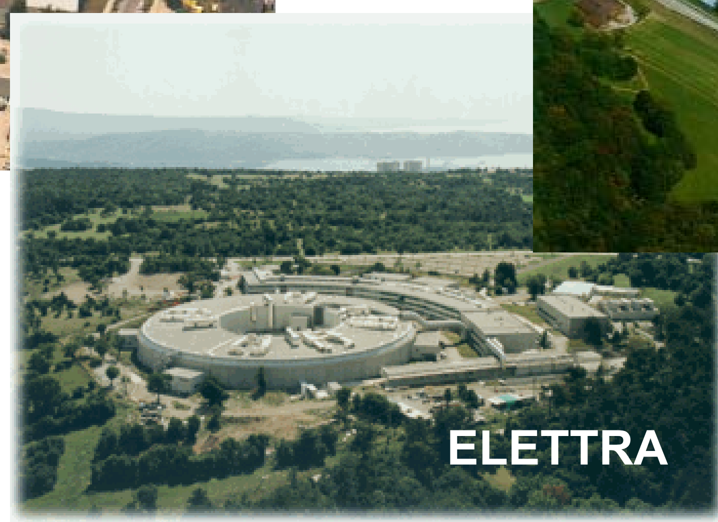


+

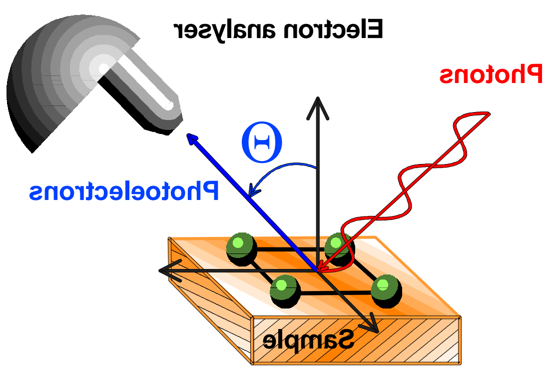


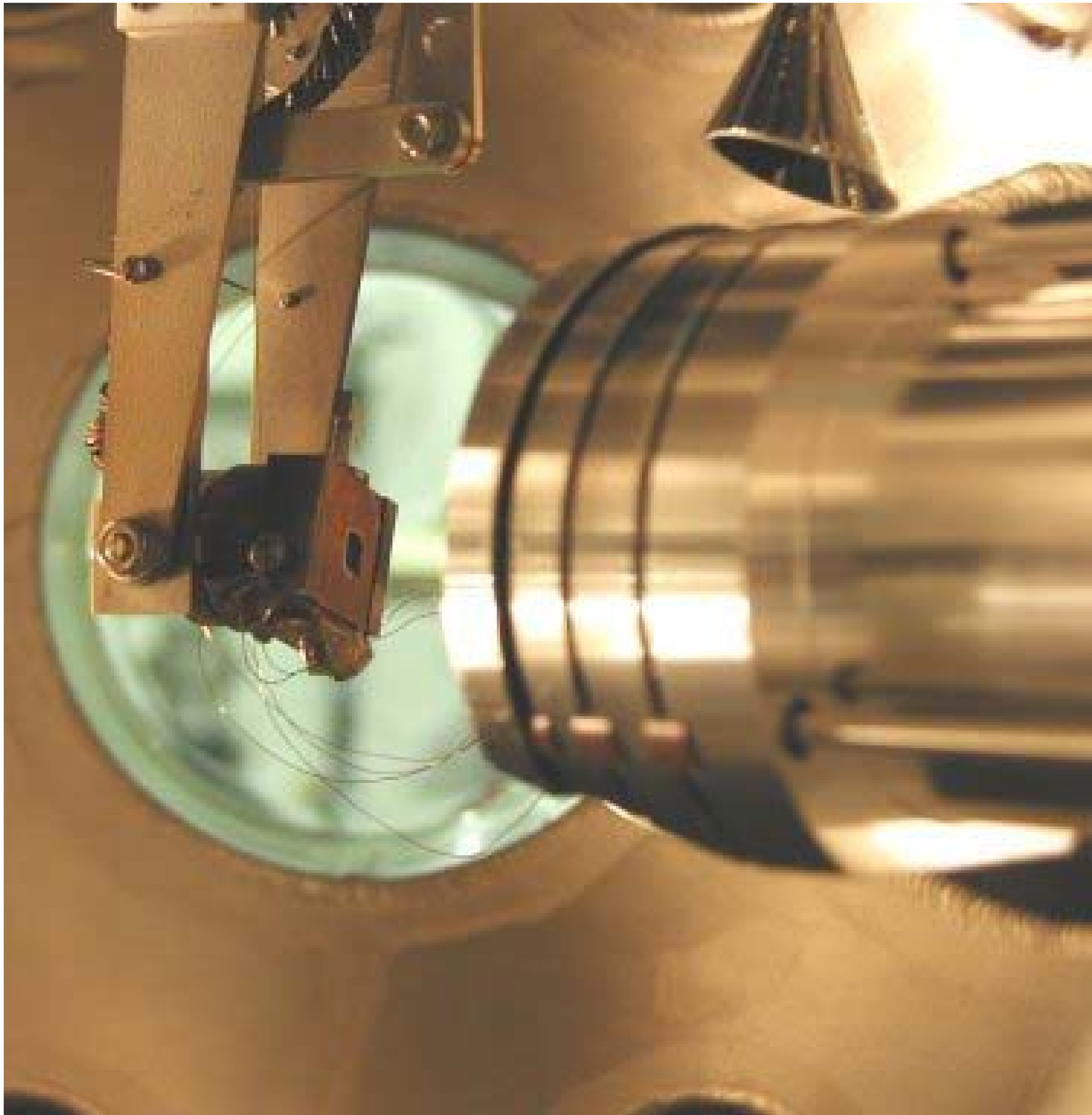
=

+

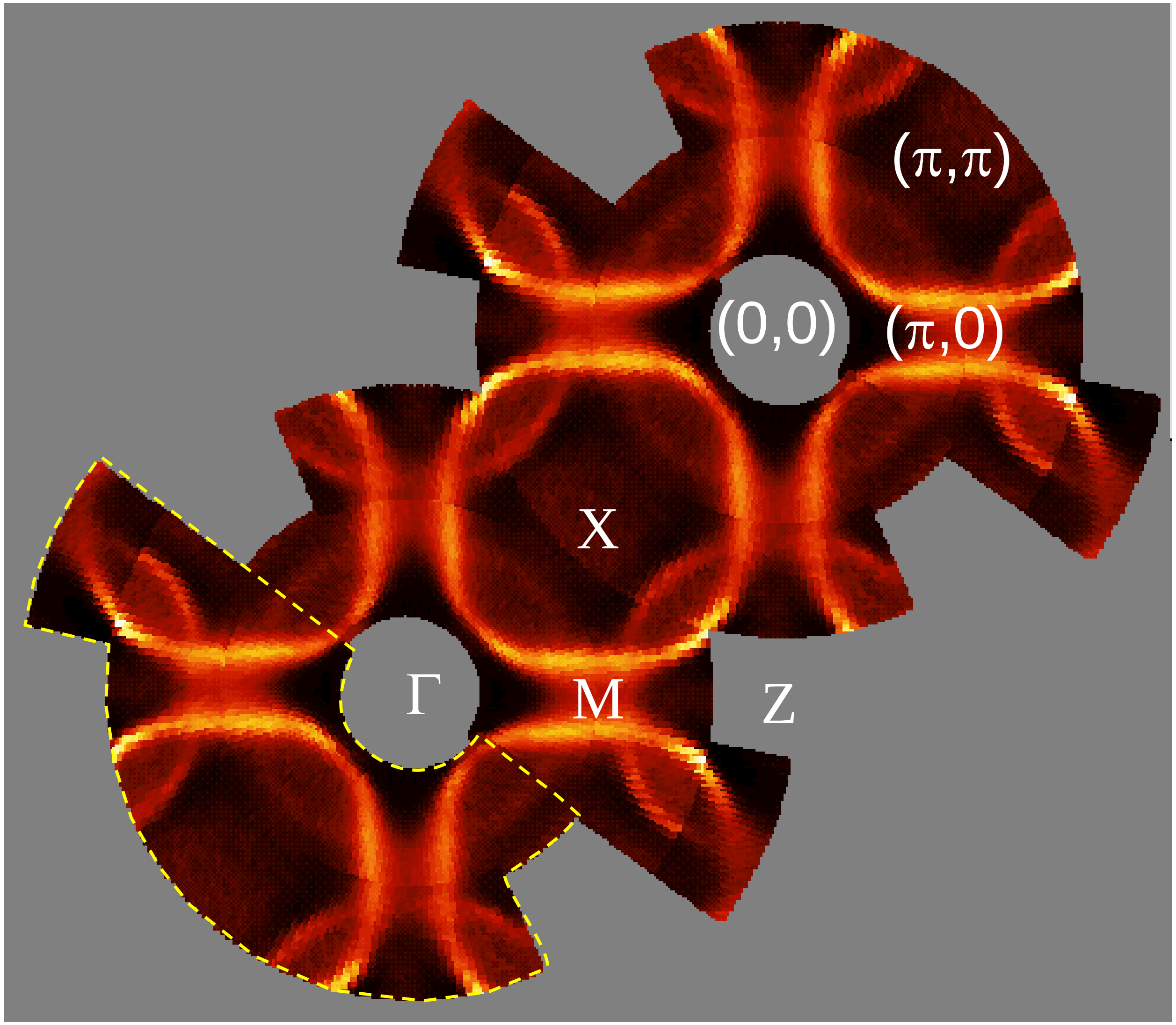


Precise Cryo-Manipulator

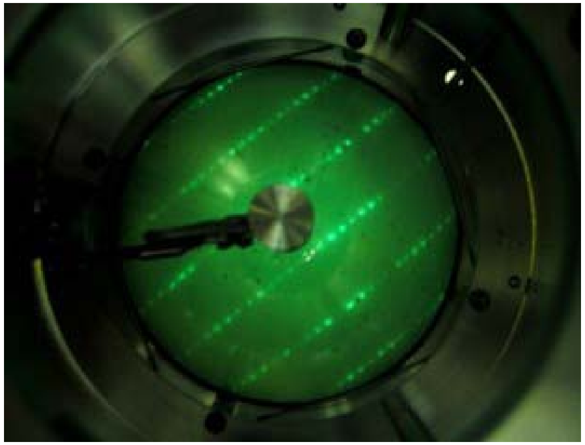


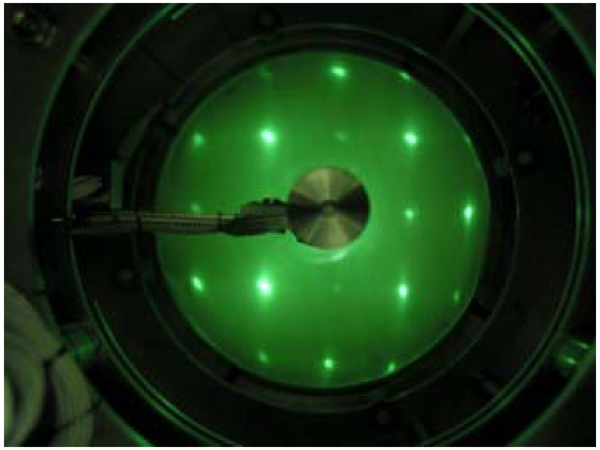


Fermi-surface map



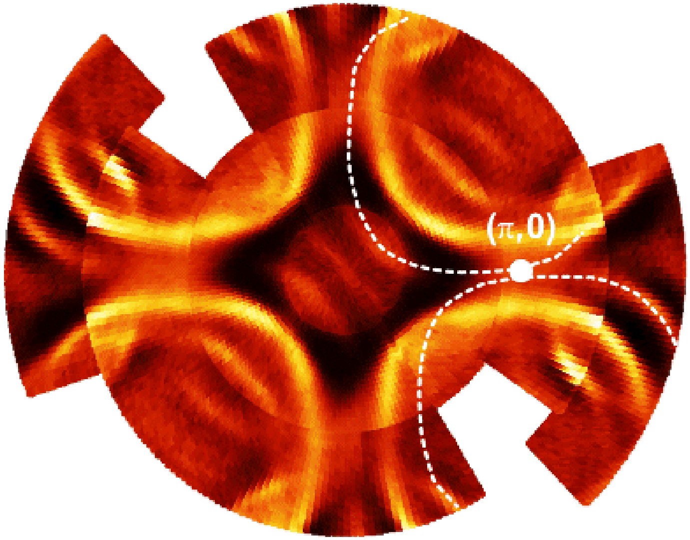
Superstructure free samples...

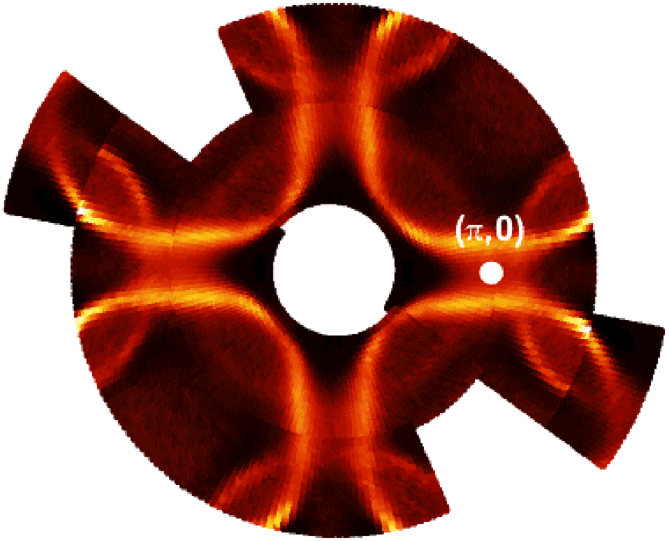




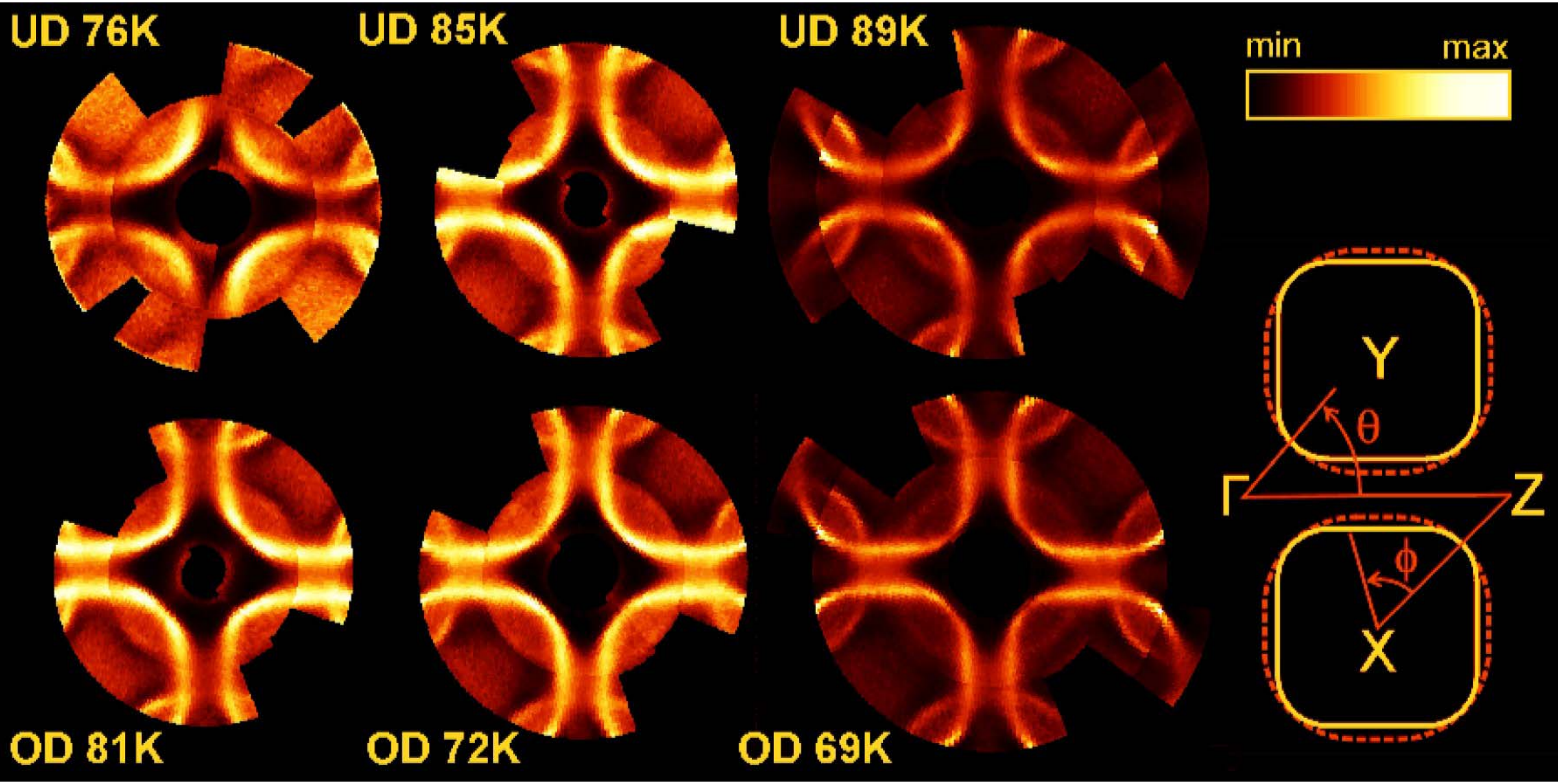
Bi2212

Pb-Bi2212





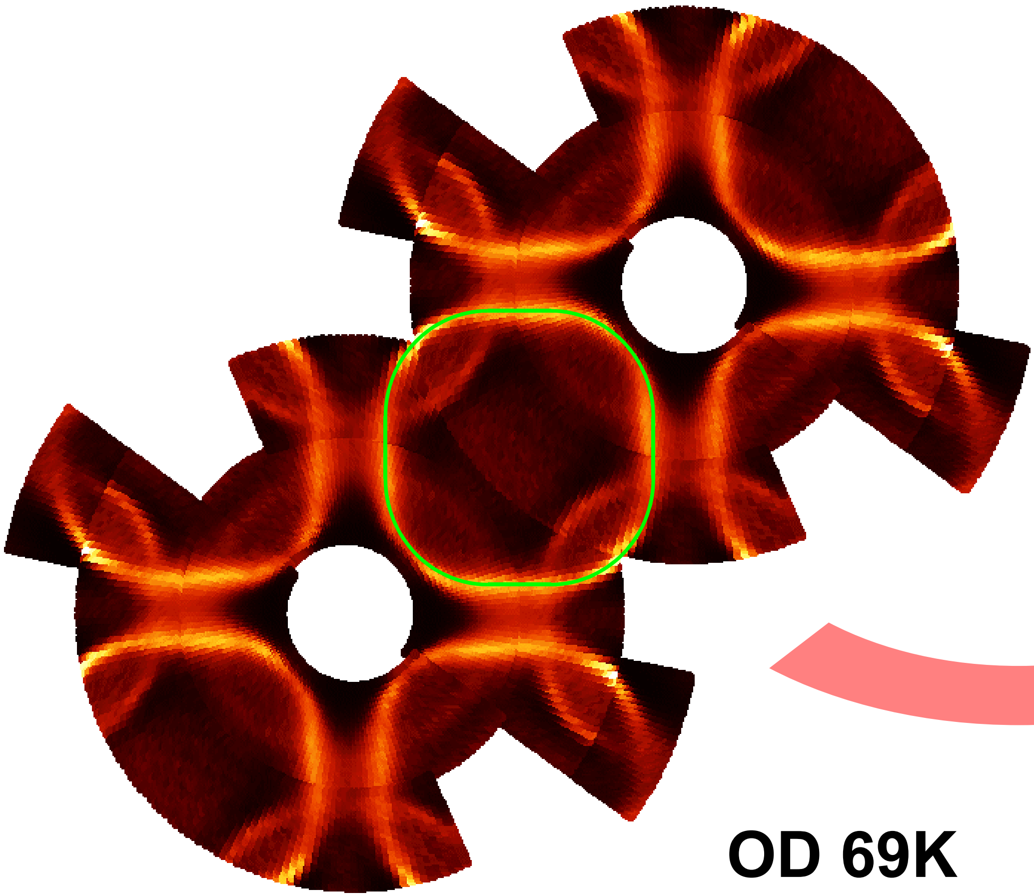
...in a wide doping range



Kordyuk *PRB* 2002

Band structure: TBF

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



$$\Delta\varepsilon \approx 0.4\,\text{eV}$$

$$t \approx 0.4\,\text{eV}$$

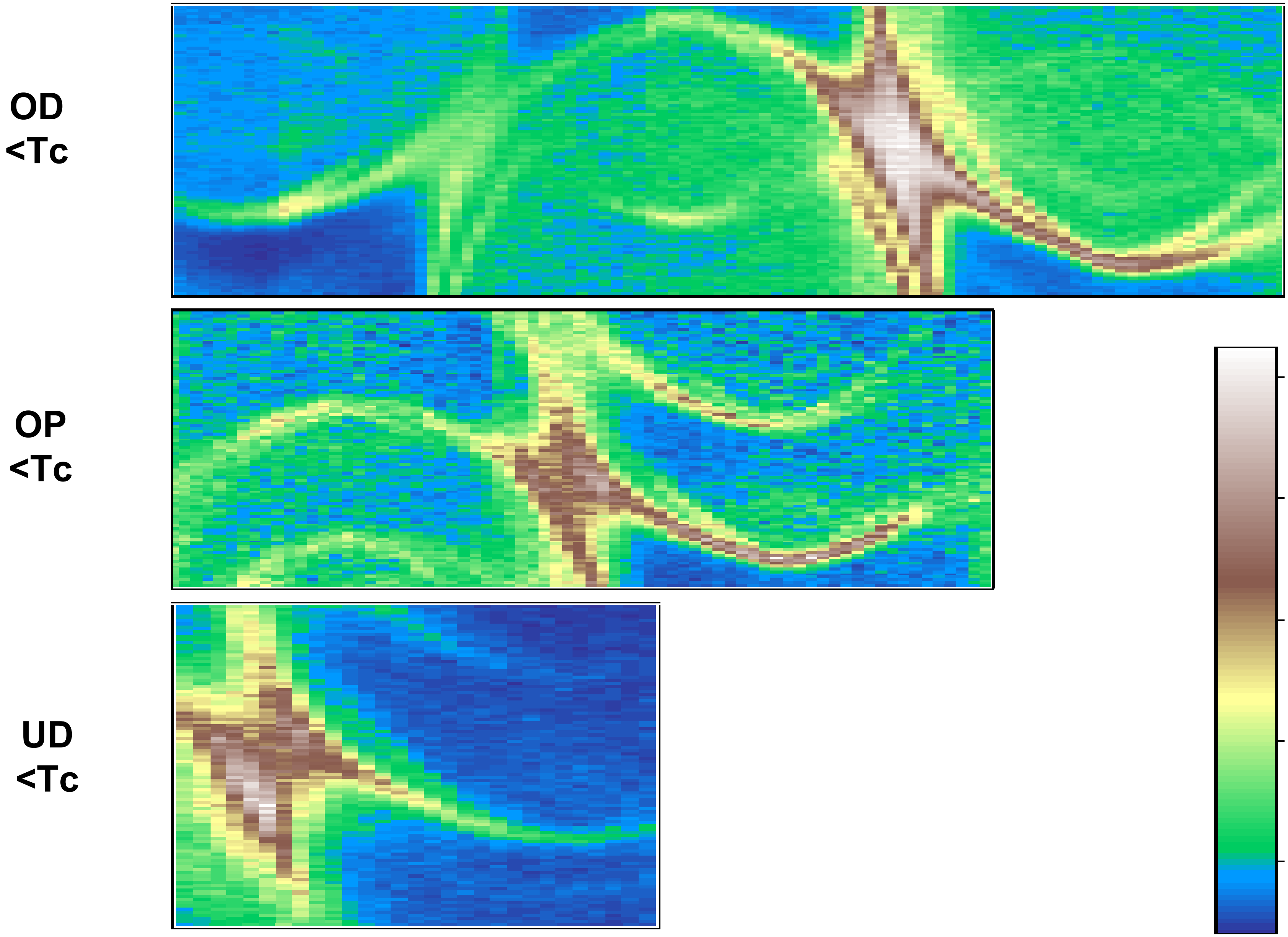
$$t' \approx 0.1\,\text{eV}$$

$$t'' \approx 0.05\,\text{eV}$$

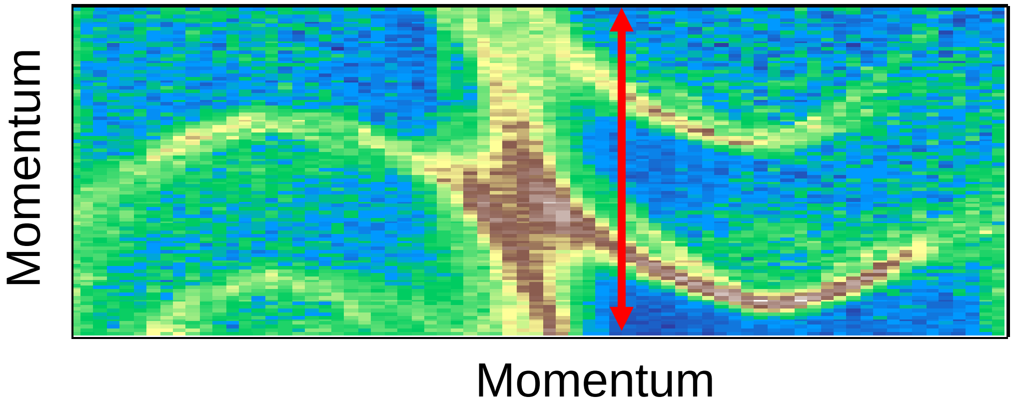
OD 69K

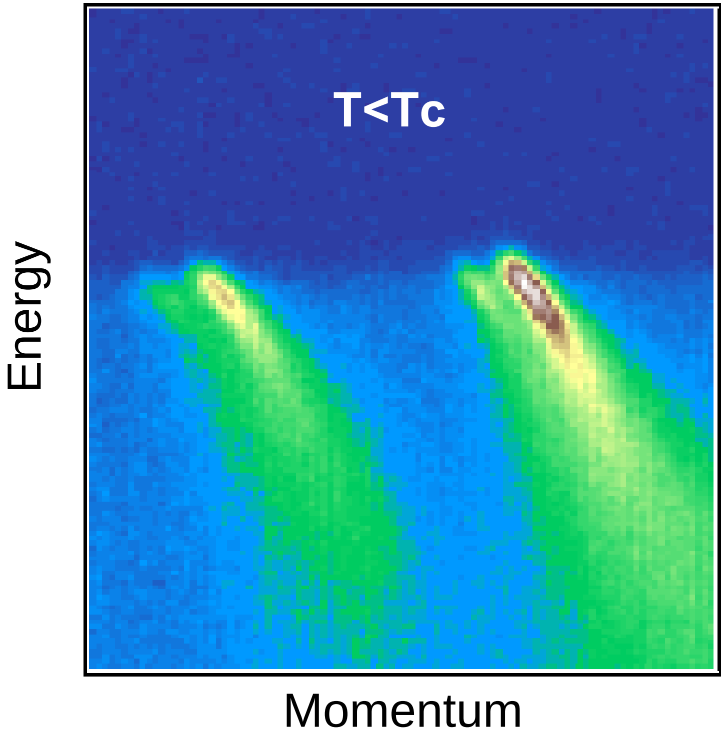
Kordyuk *PRB* 2003

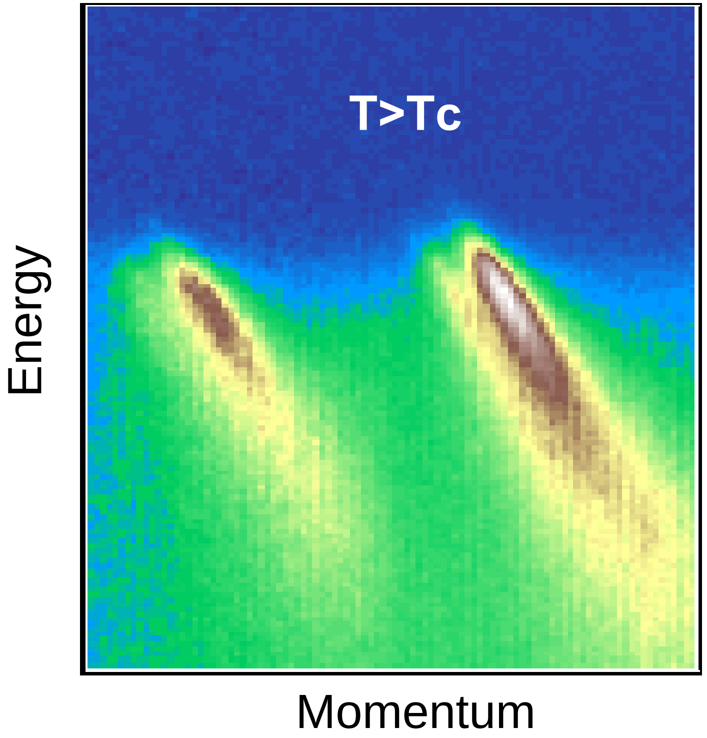
High precision Fermi surface mapping



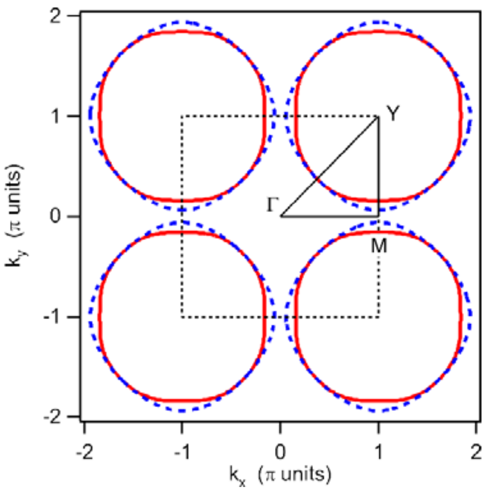
Bilayer splitting in OP Bi-2212 in normal state

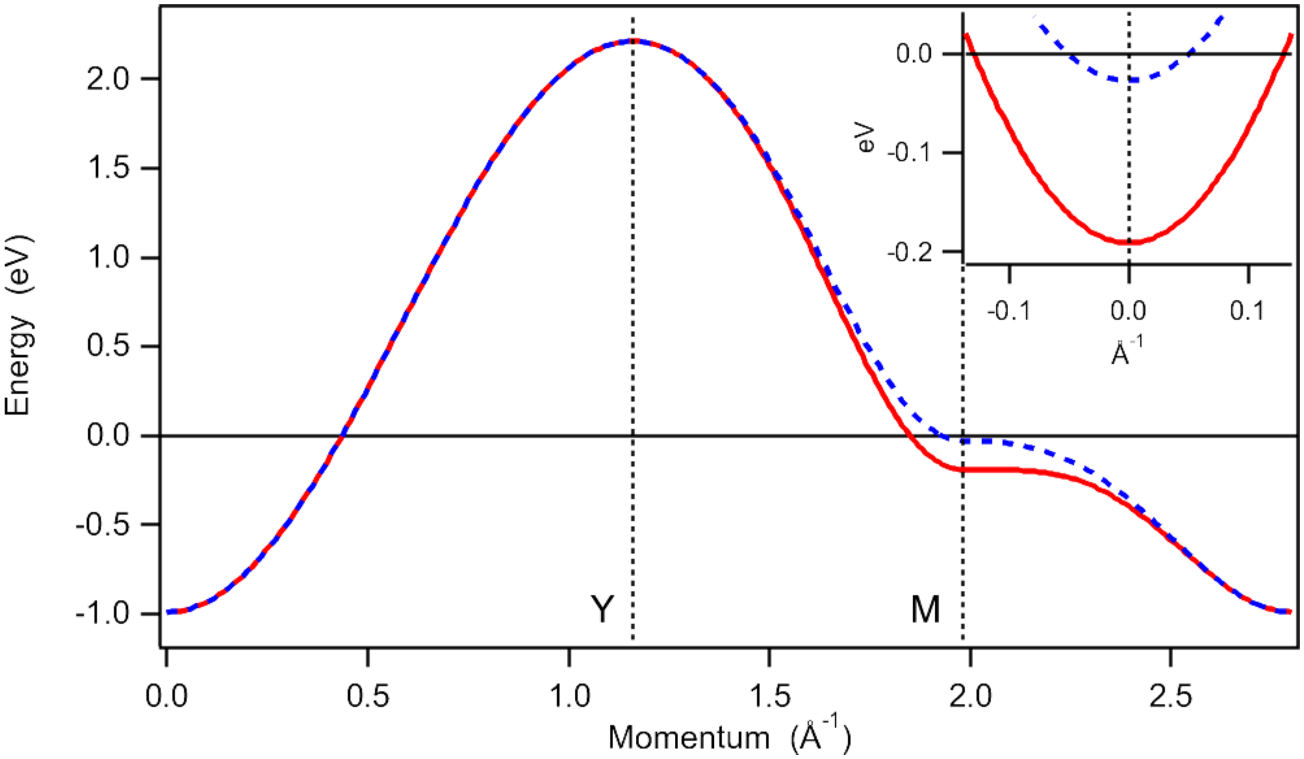




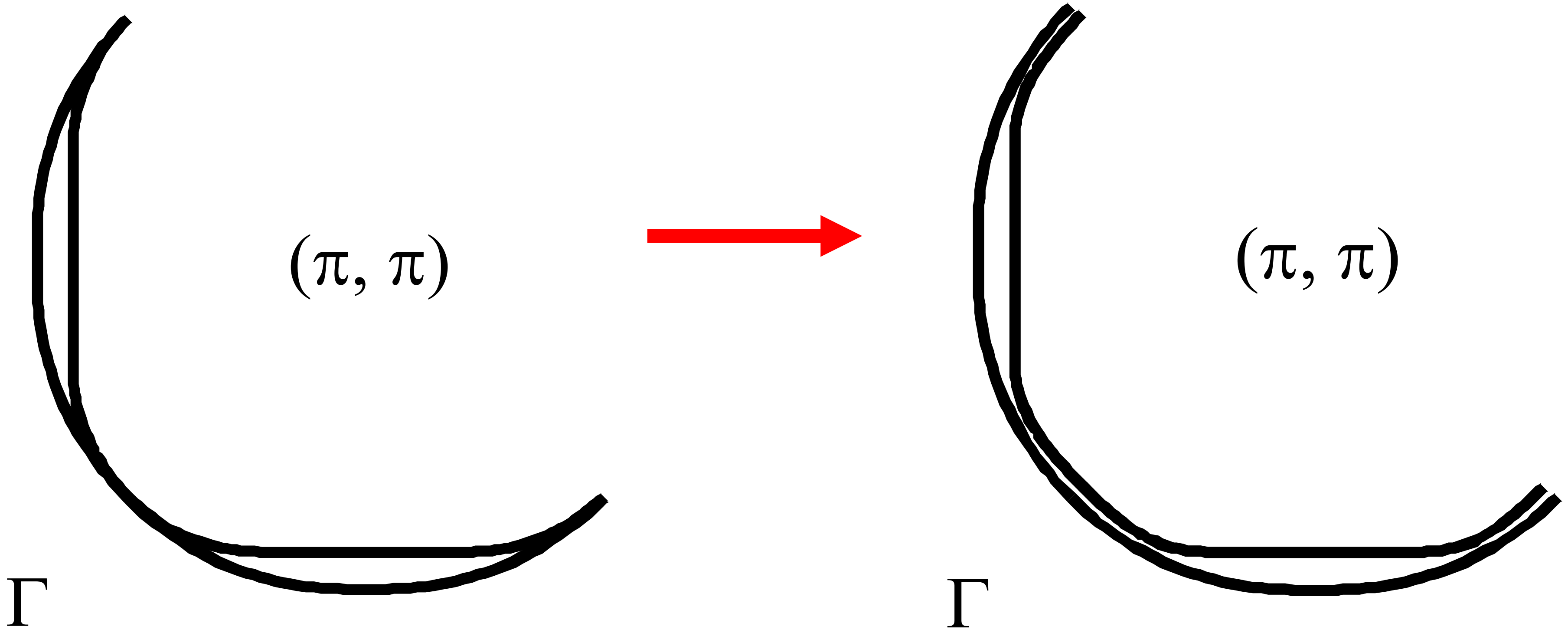


Bare band structure

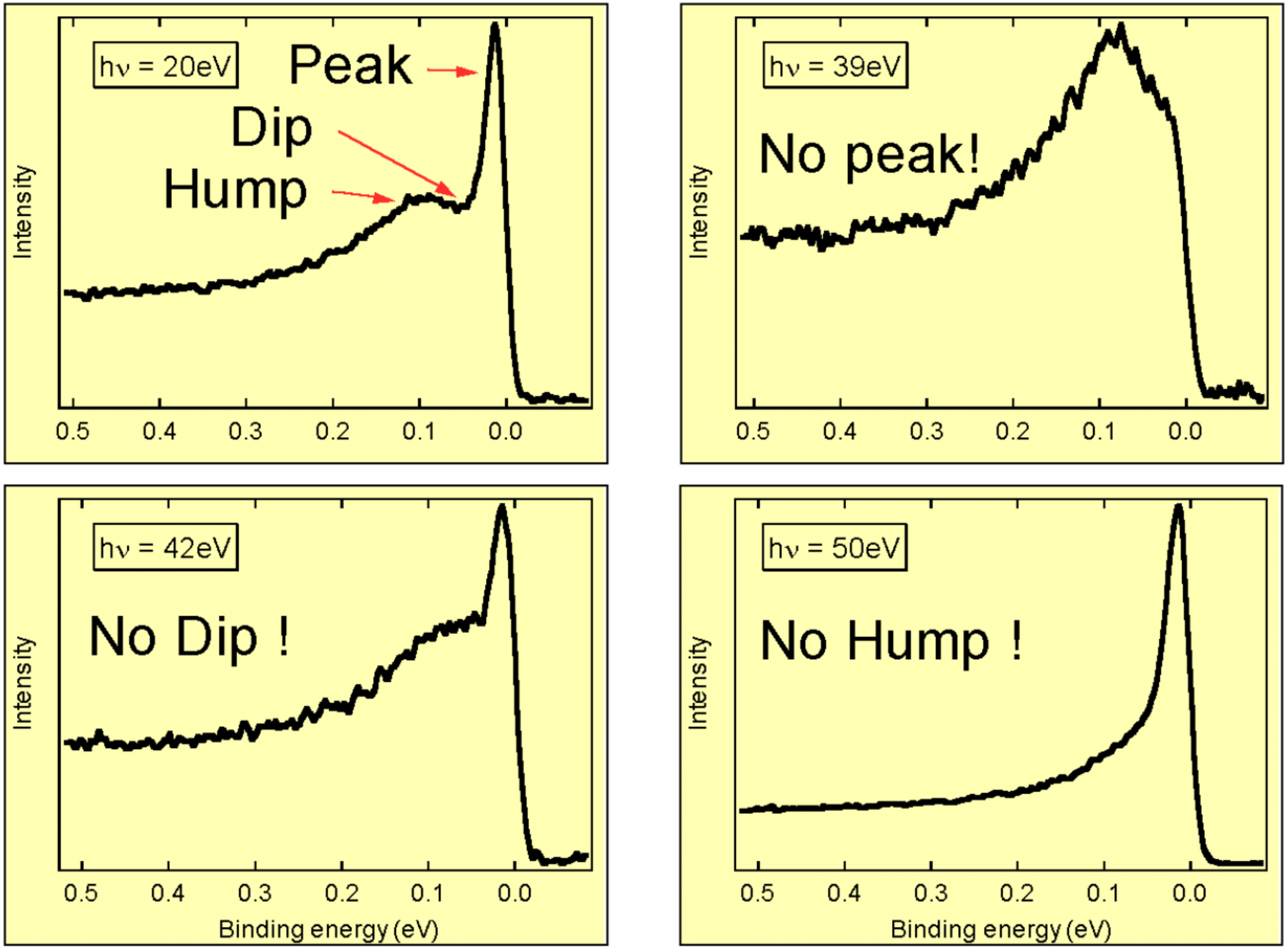




Kordyuk *PRB* 2003

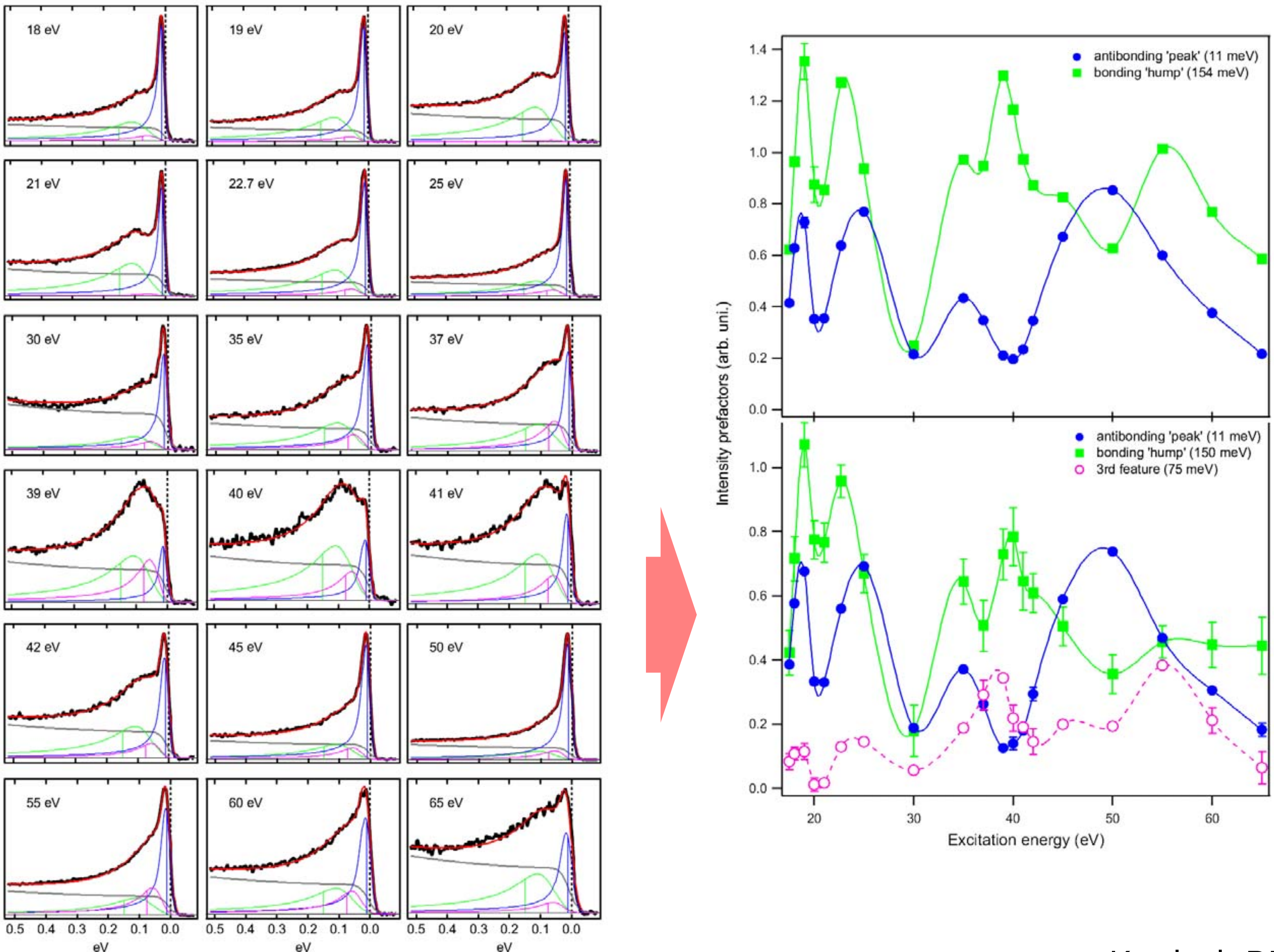

(π, π)
Γ
(π, π)
Γ

Excitation energy variation: PDH in OD



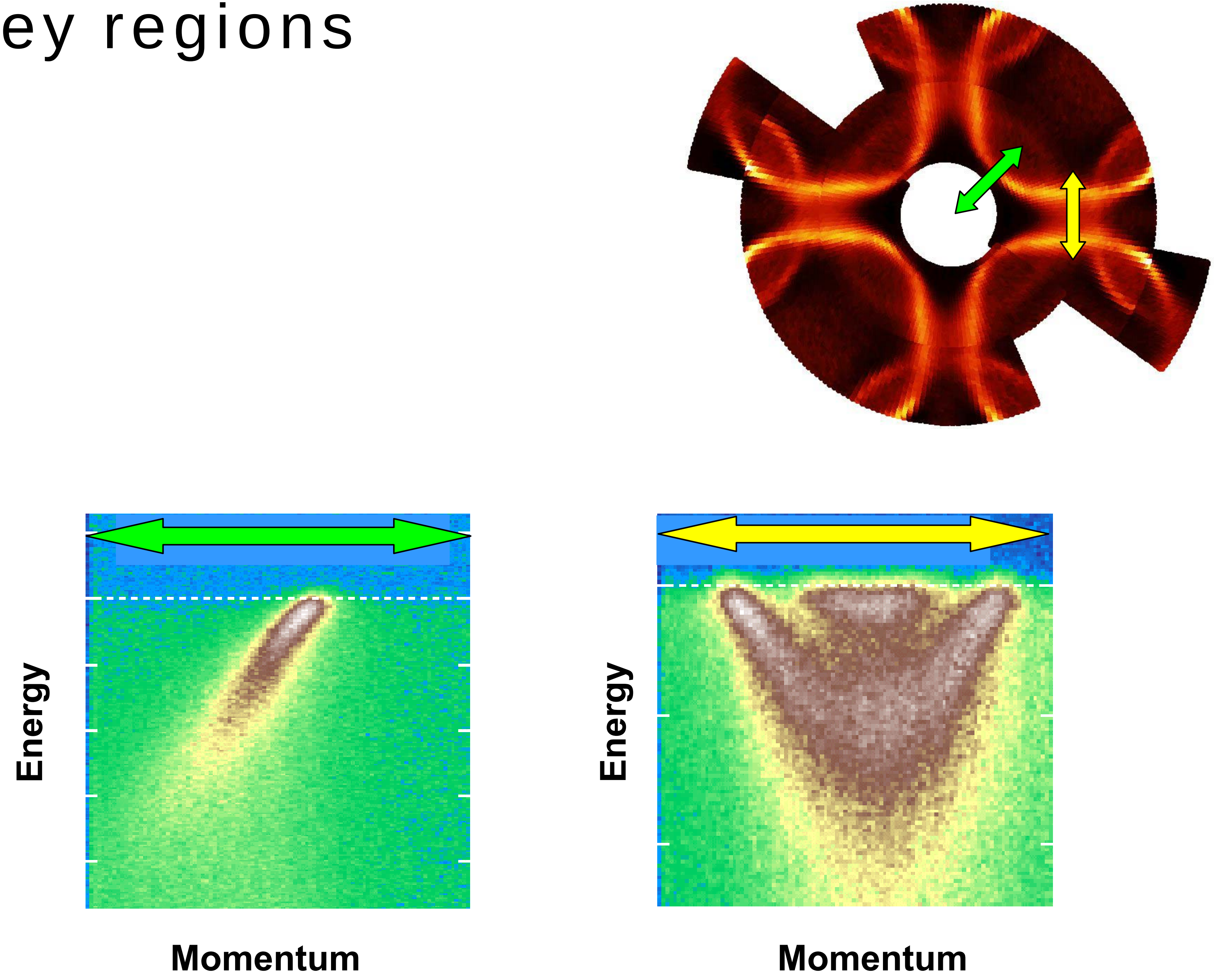
Kordyuk *PRL* 2002

Excitation energy variation: PDH in OD

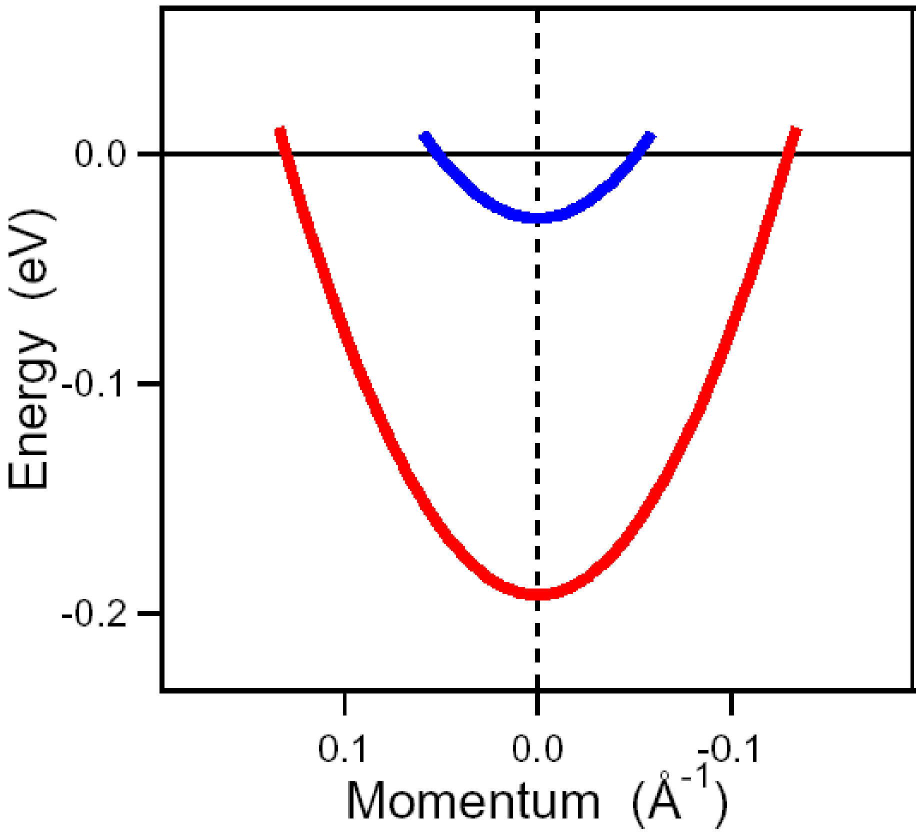


Kordyuk *PRL* 2002

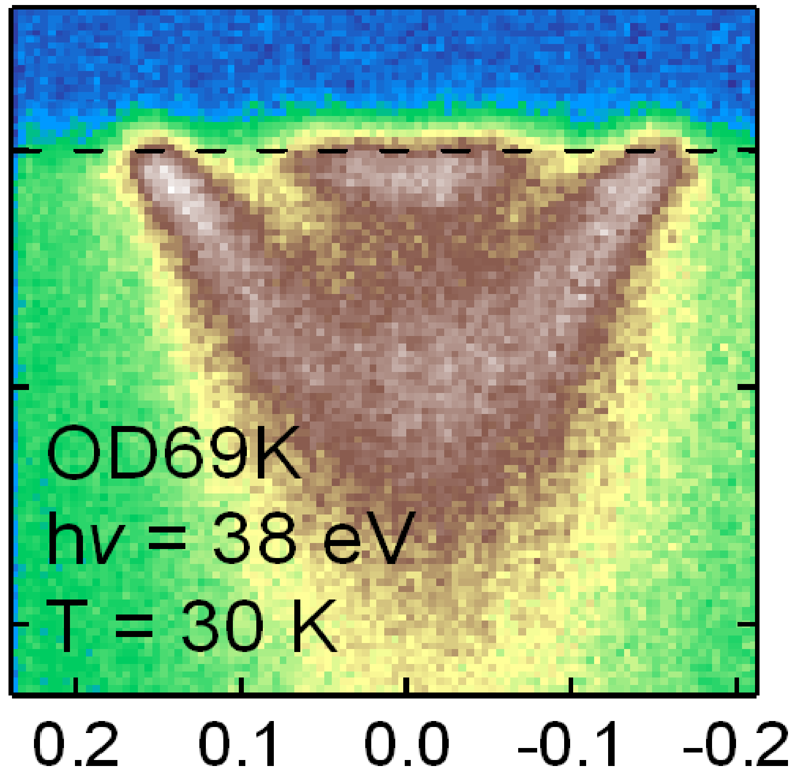
Key regions



"XMY cut"

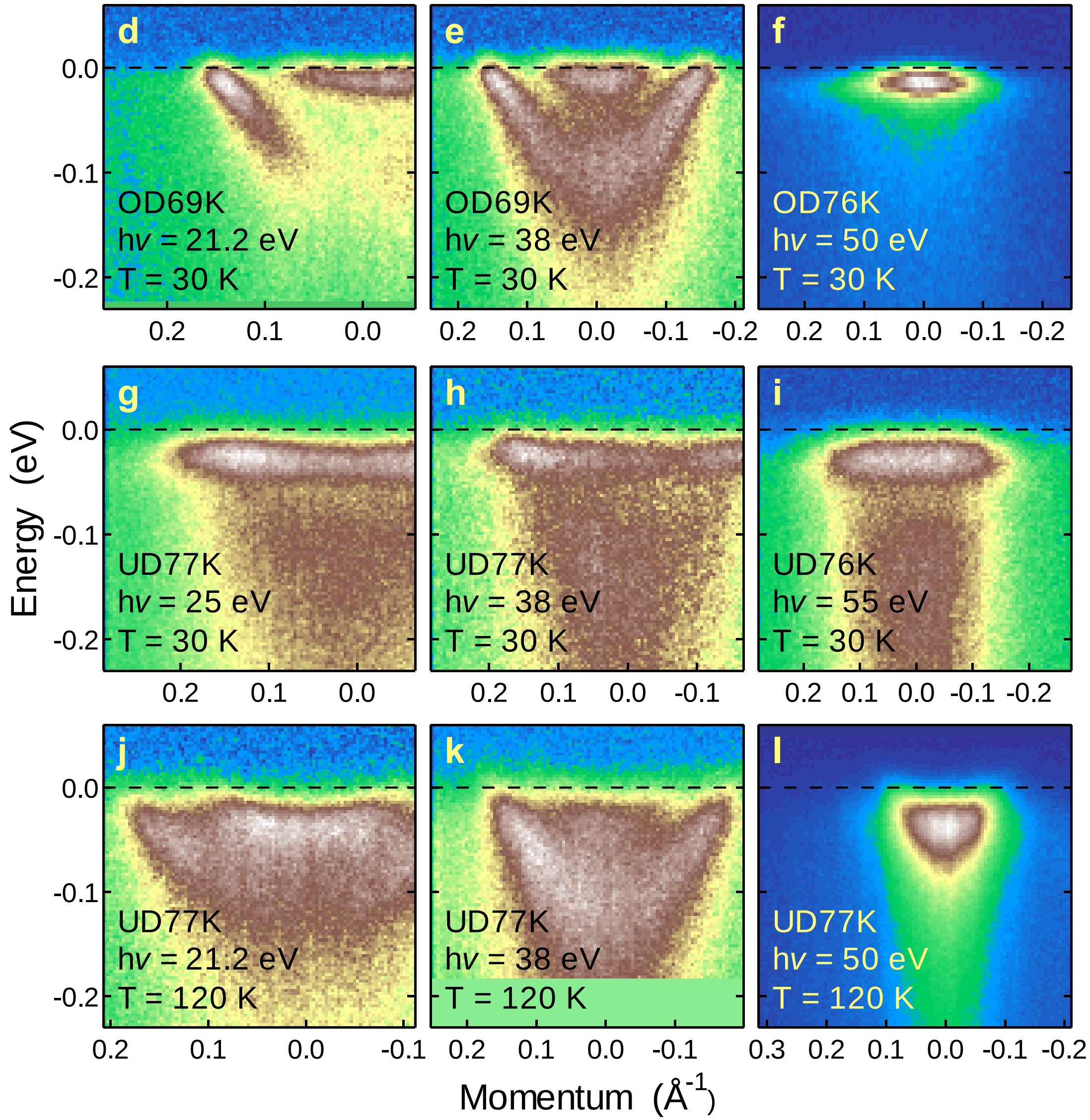


0.0
-0.1
-0.2
Energy (eV)
0.1
0.0
-0.1
Momentum (Å^{-1})



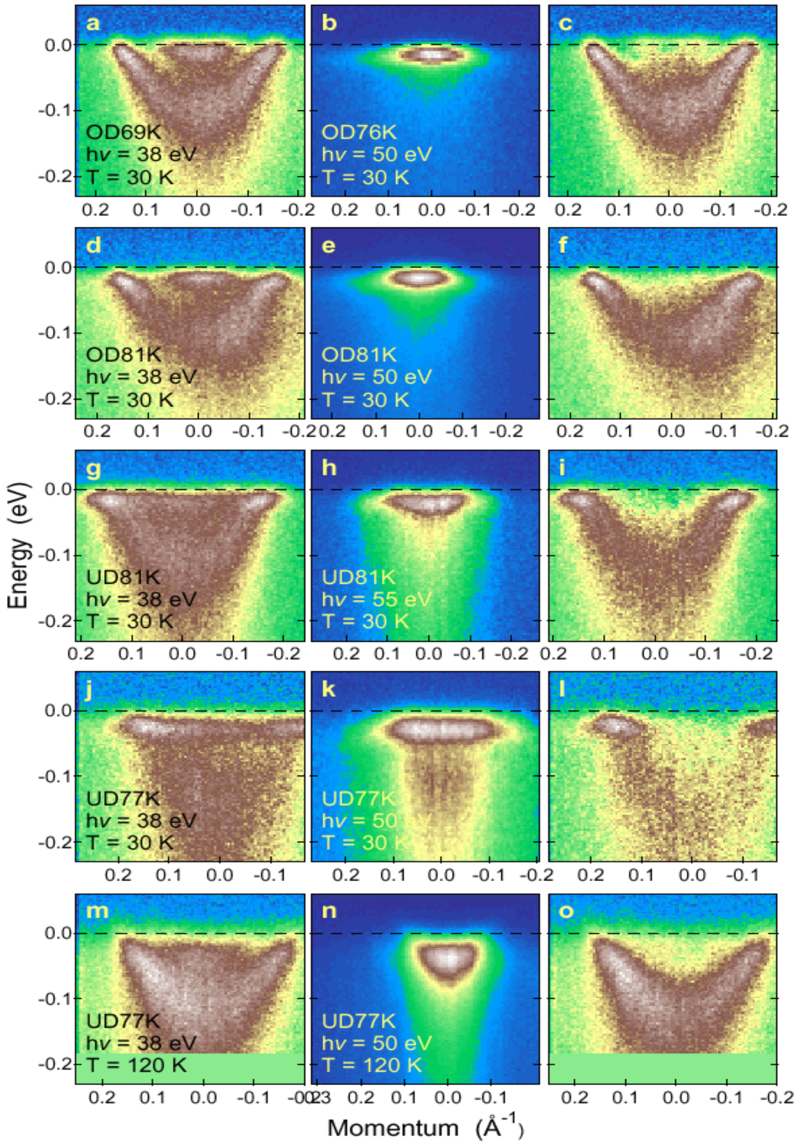
OD69K
hν = 38 eV
T = 30 K
0.2
0.1
0.0
-0.1
-0.2

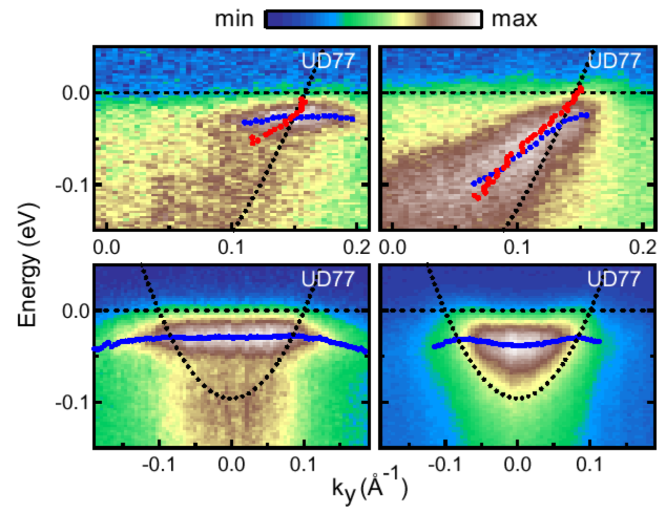
Interaction with a mode

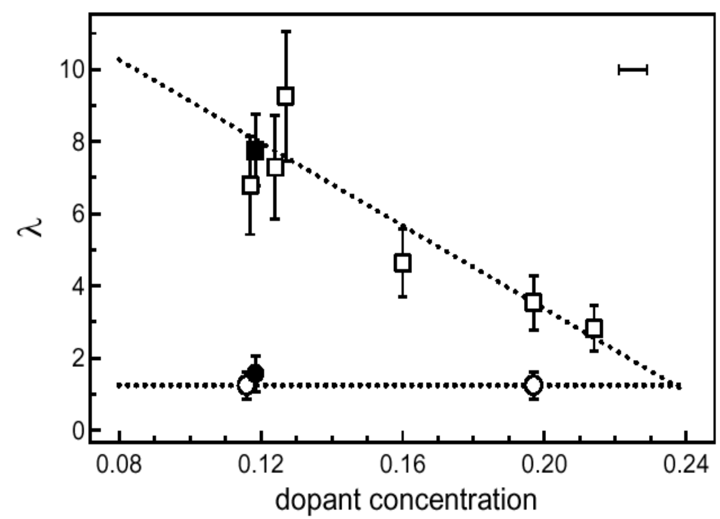


Borisenko *PRL* 2003

Interaction with a mode







Kim *PRL* 2003

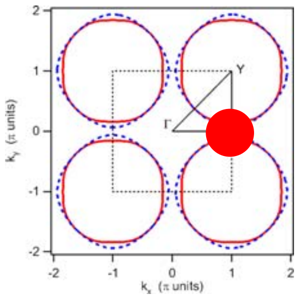
Electrons couple to ...

Doping dependence: UD↑
OD↓

Temperature dependence: $<T_c$

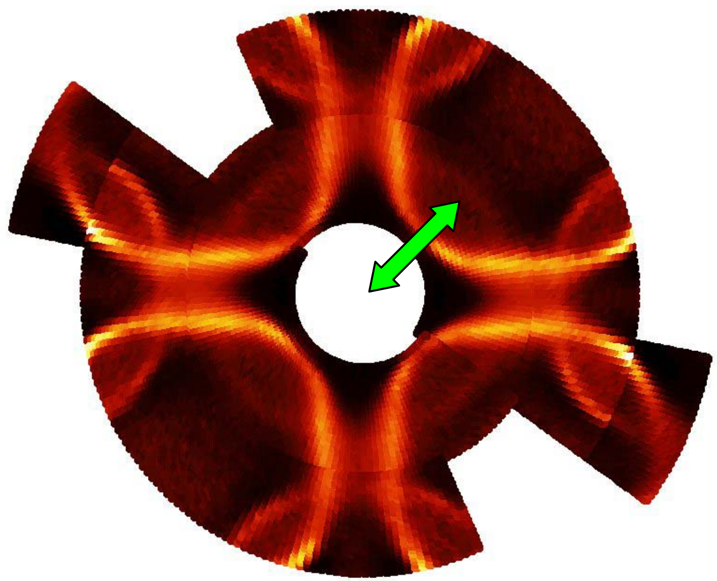
Energy ~ 40 meV

k-dependence:

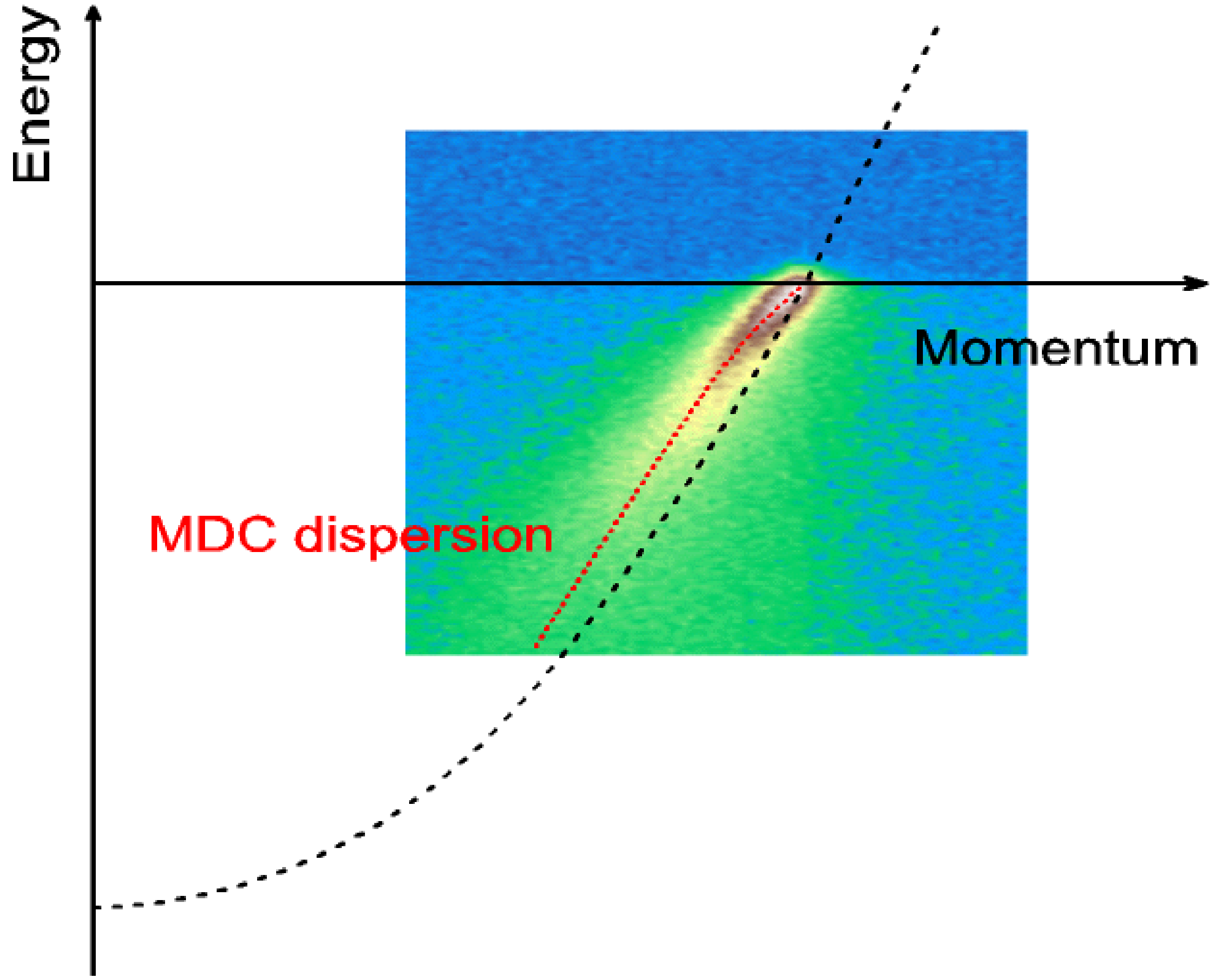


spin fluctuations

GX

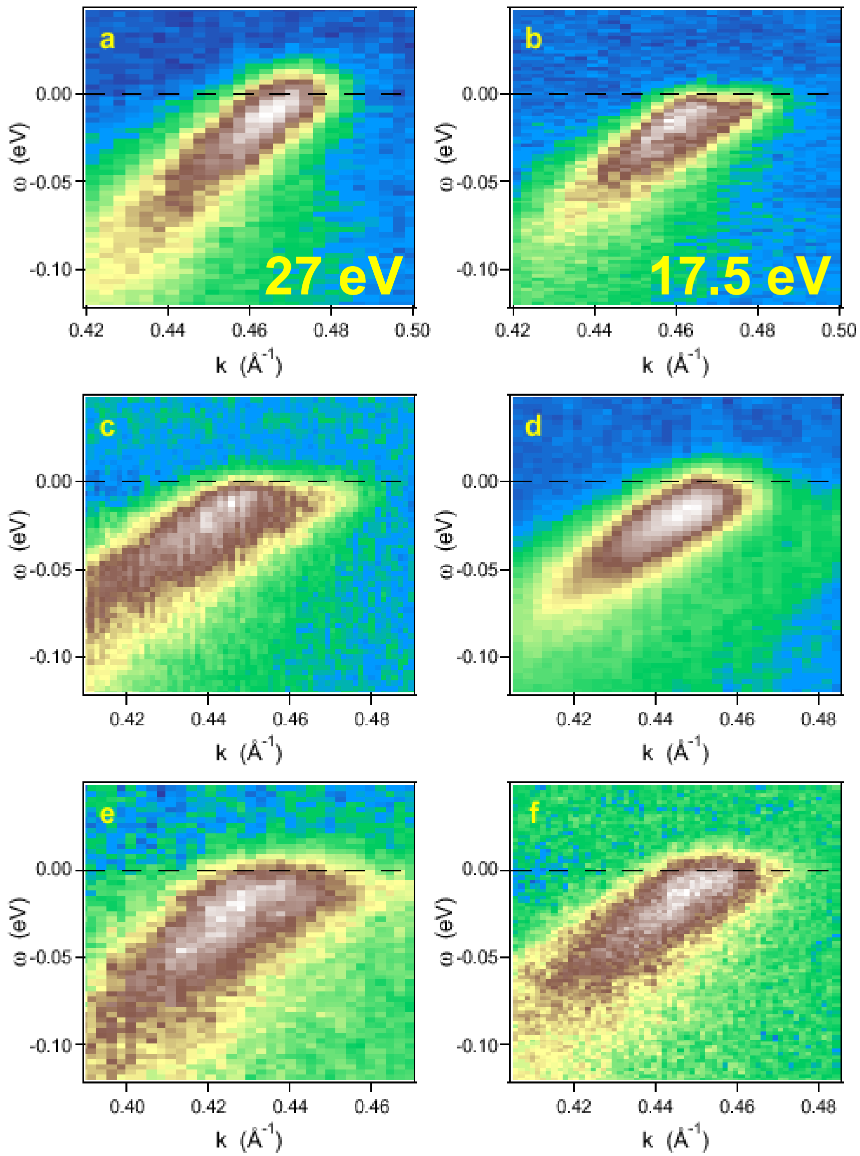


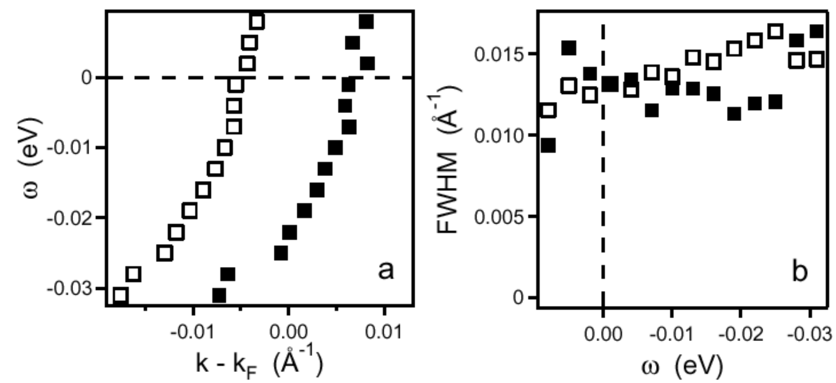
Basics: electron dispersion

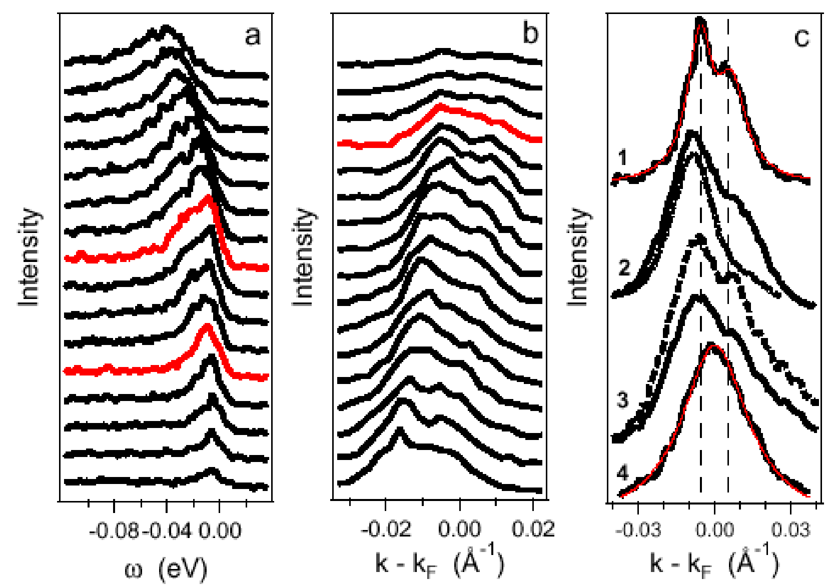


Nodal splitting

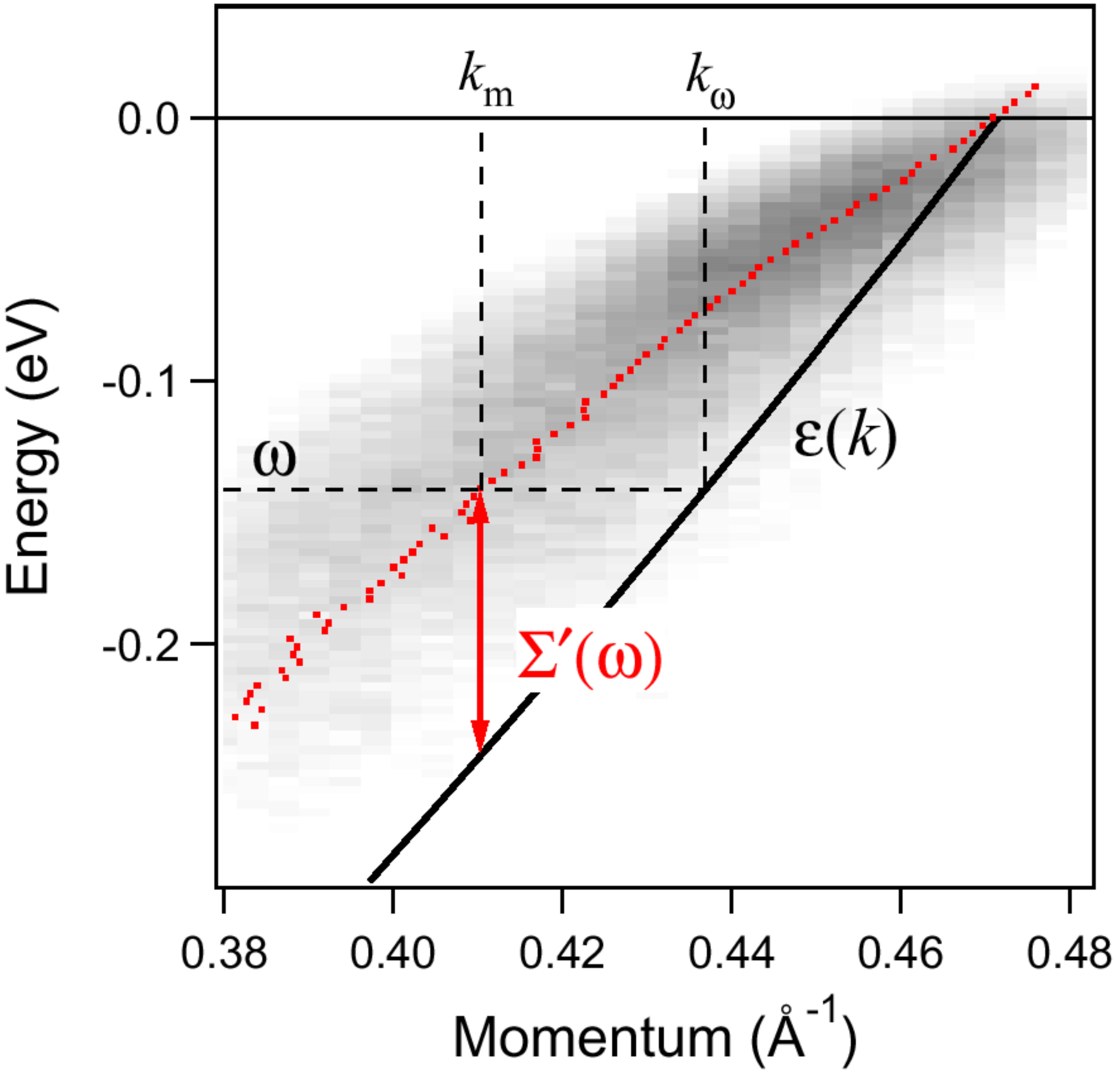
$$\Delta k = 0.012 \ \ 1/\text{Å}$$
$$\Delta \varepsilon = 50 \ \ \text{meV}$$





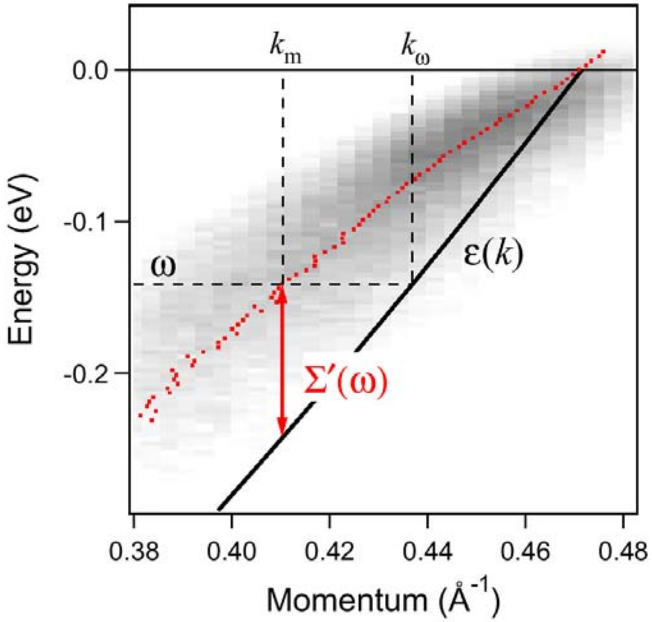


Bare dispersion



Self-energy approach

$$A(\omega, \mathbf{k}) = -\frac{1}{\pi} \frac{\Sigma''(\omega)}{(\omega - \varepsilon(\mathbf{k}) - \Sigma'(\omega))^2 + \Sigma''(\omega)^2}$$



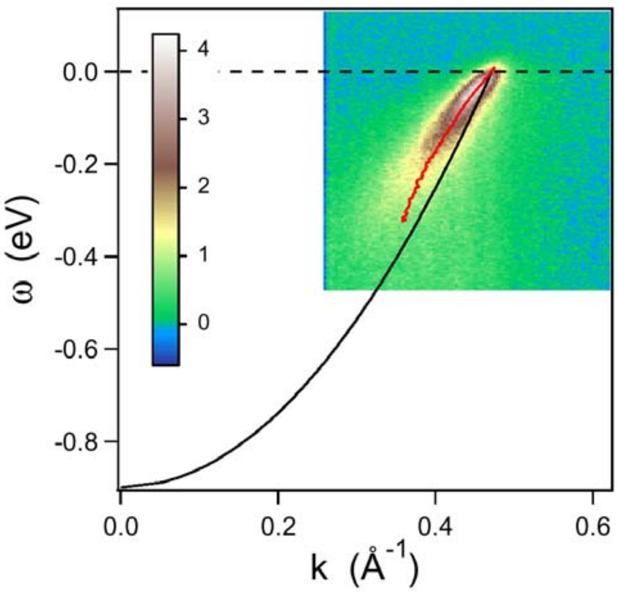
$$\Sigma'(\omega) = \omega - \varepsilon(k_m)$$

$$\Sigma''(\omega) = -v_F W(\omega)$$

Self-energy approach

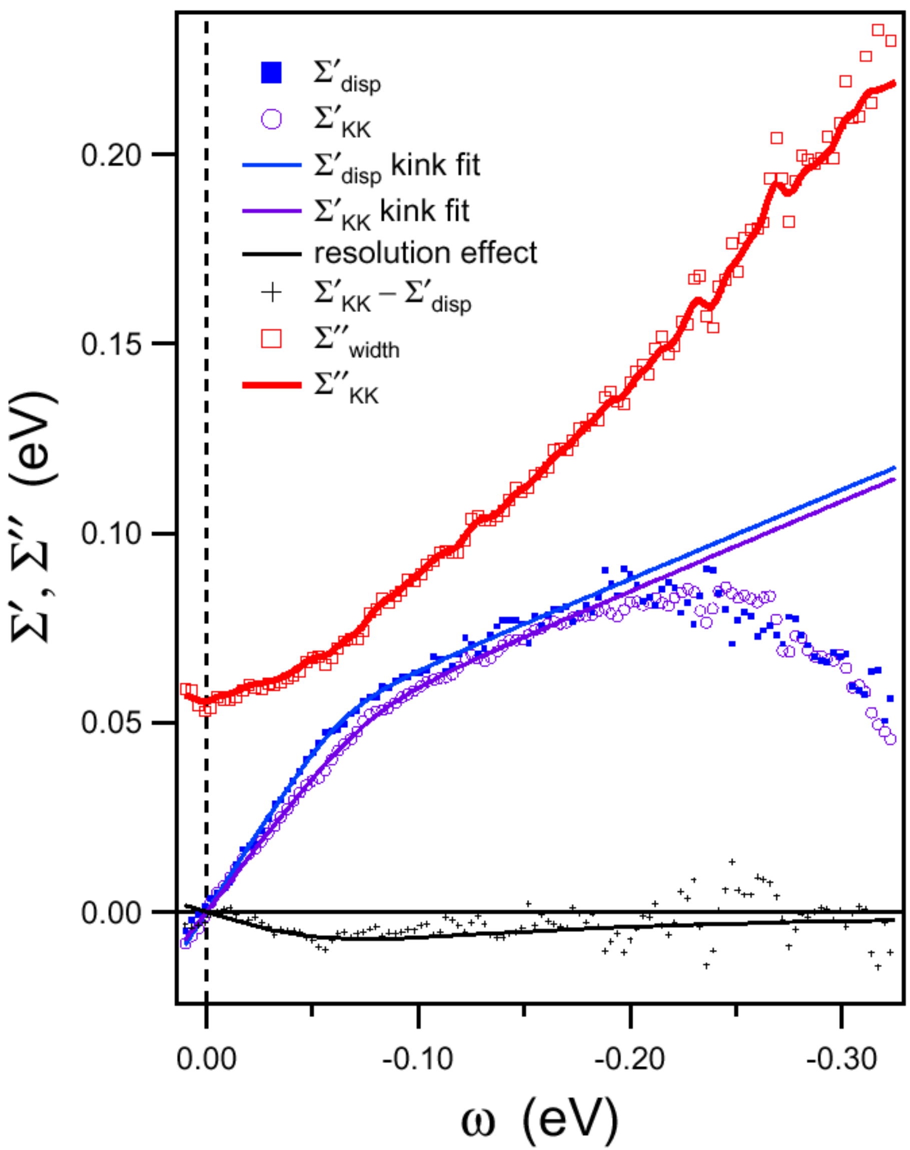
$$\Sigma'(\omega) = \frac{v_F}{2}(k_m^2(\omega) - k_F^2) + \omega,$$

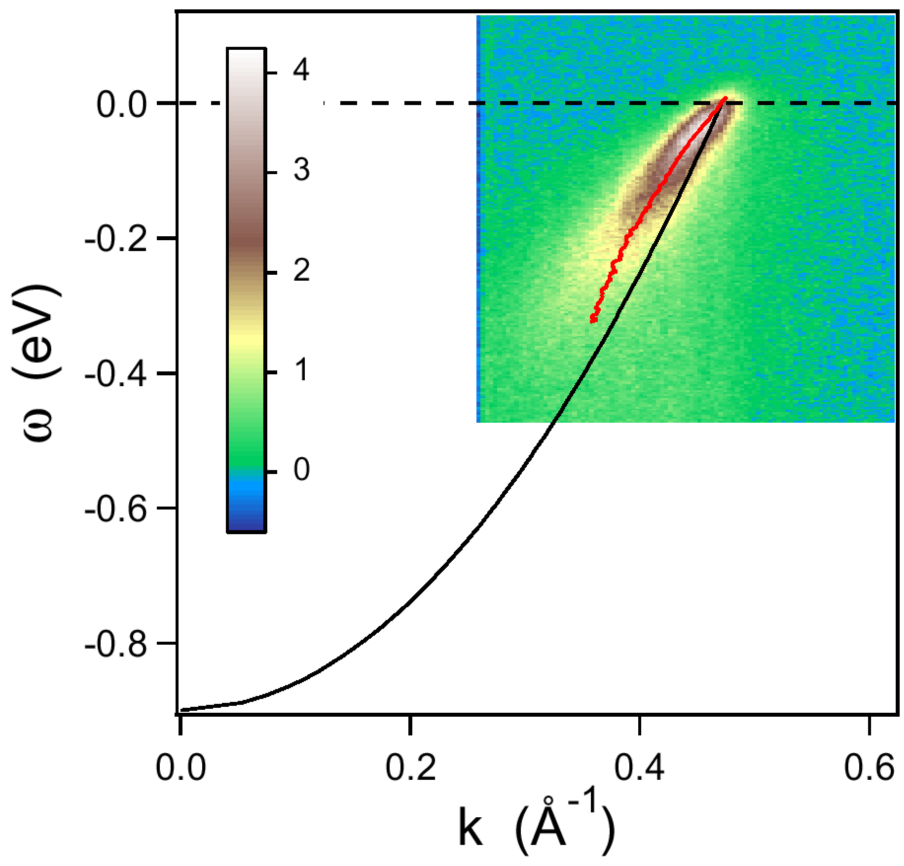
$$\Sigma''(\omega) = -v_F W(\omega)\sqrt{k_m^2(\omega) - W^2(\omega)}.$$



$\Sigma'(\omega) = \mathrm{KK}\ \Sigma''(\omega)$

Bare dispersion

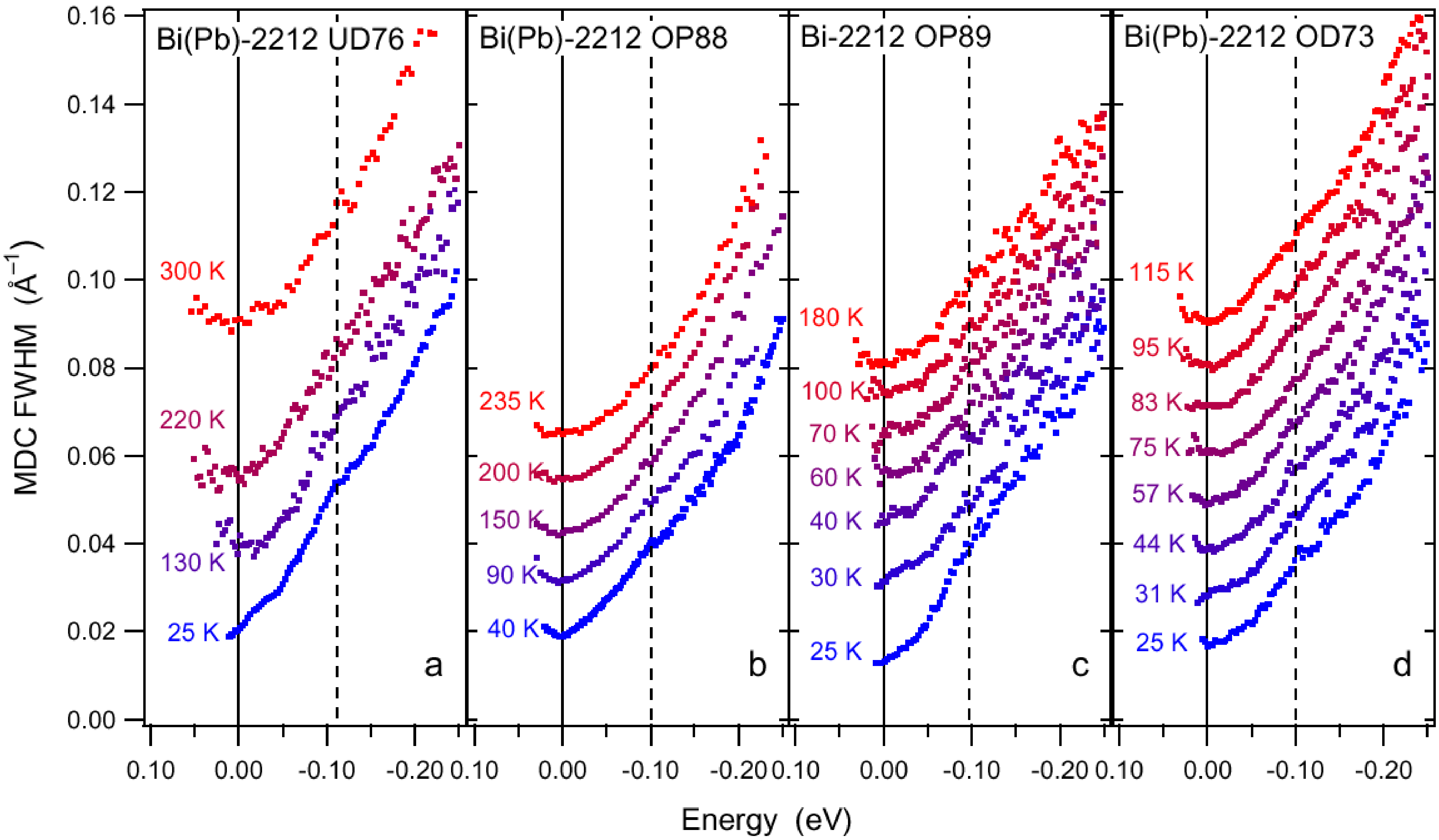




$$v_F = 3.82 \pm 0.17 \text{ eVÅ}$$

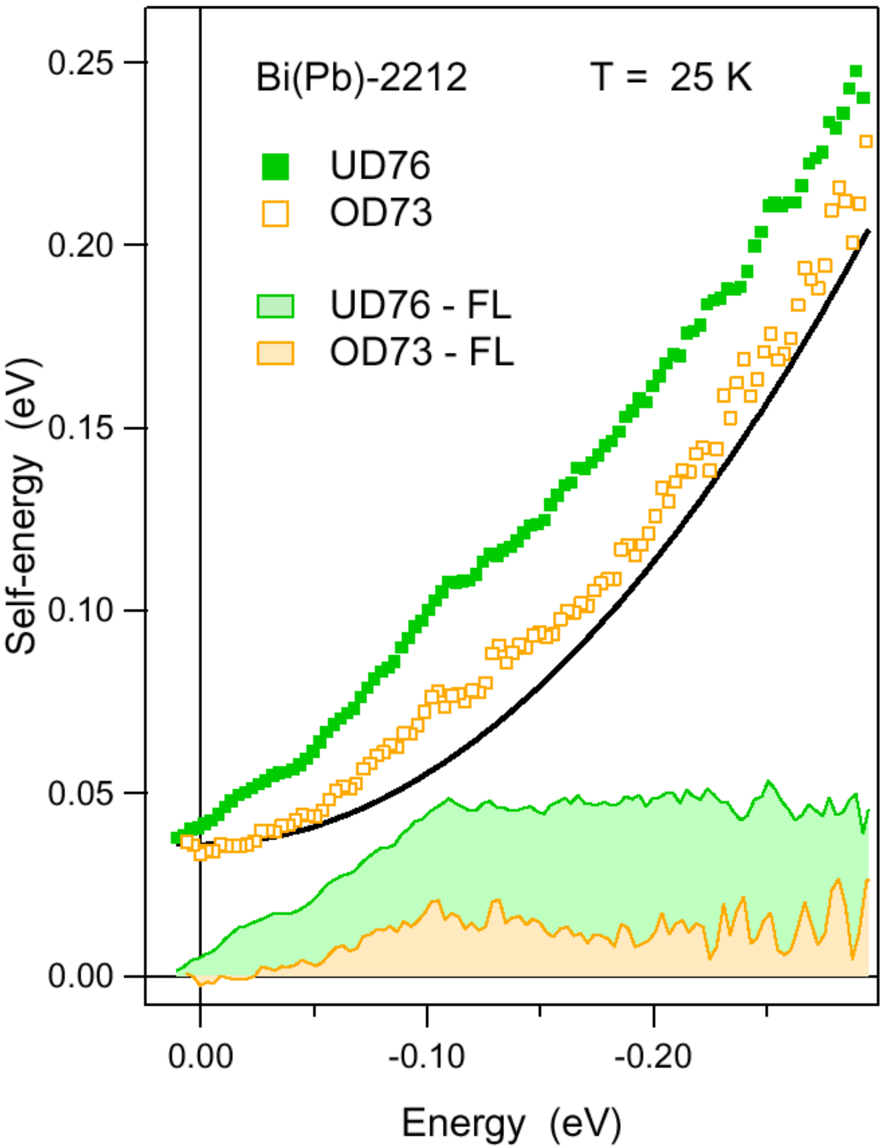
$$\lambda = 0.87 \pm 0.12$$

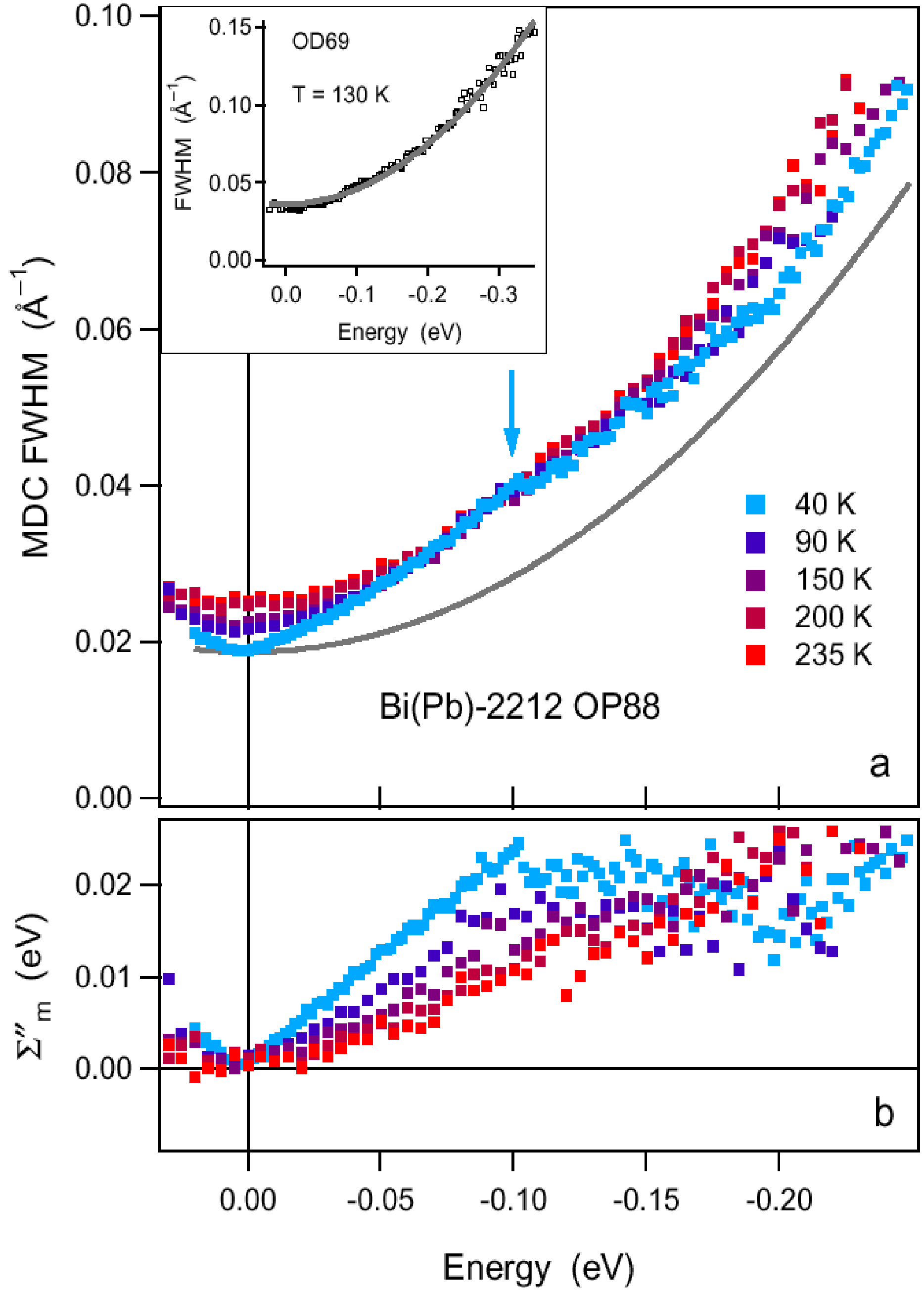
Scattering rate kink



Kordyuk *PRL* 2004

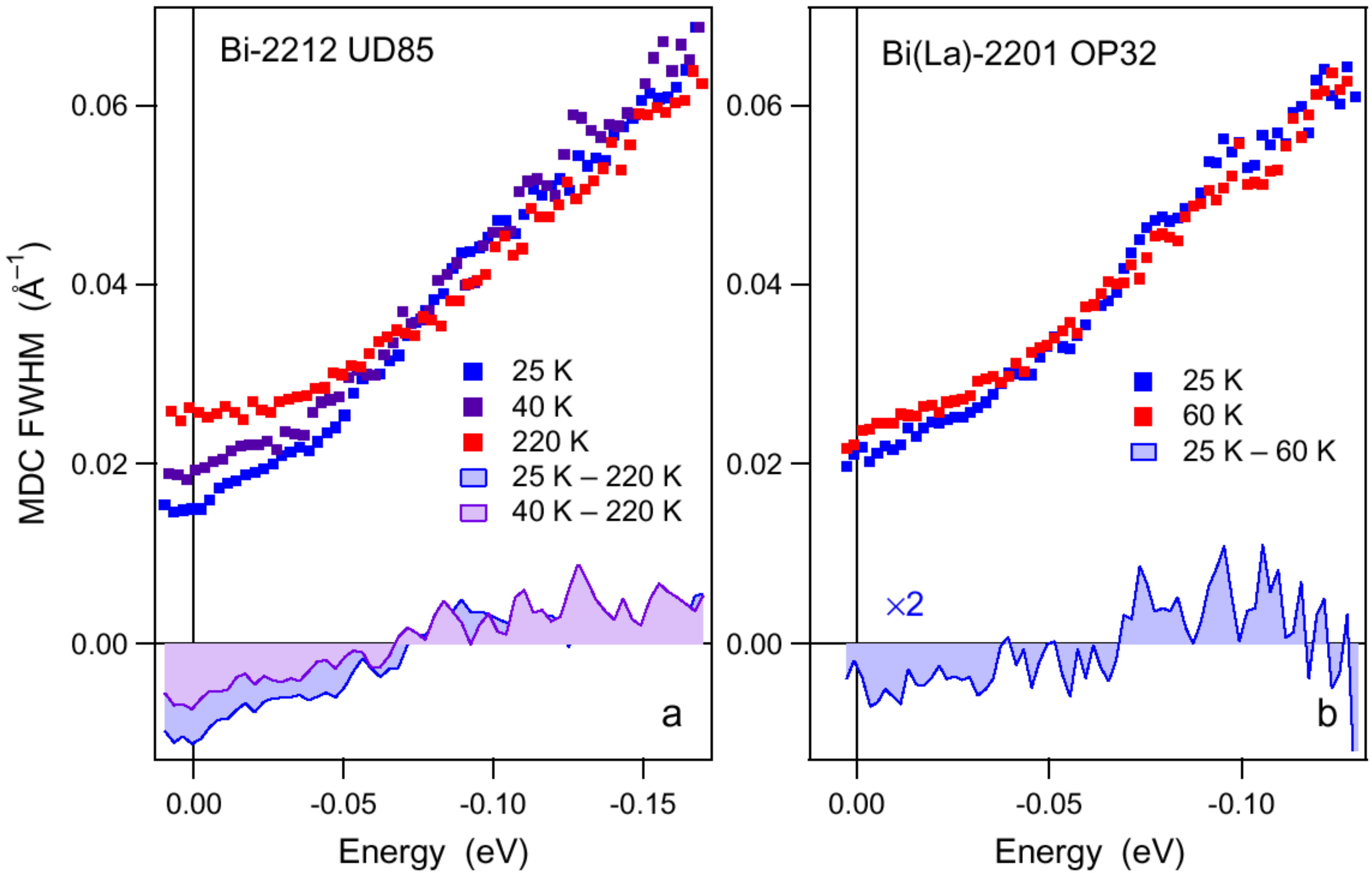
Scattering rate





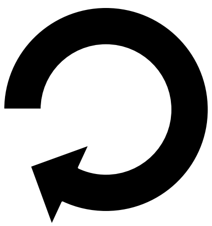
Kordyuk *PRL* 2004

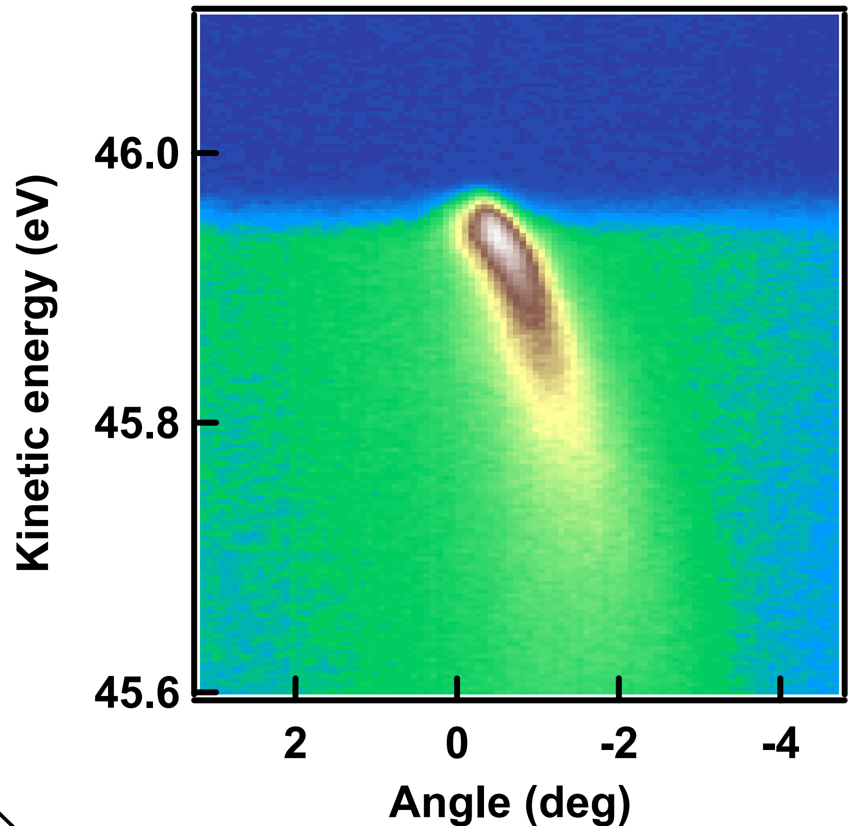
Scattering rate kink

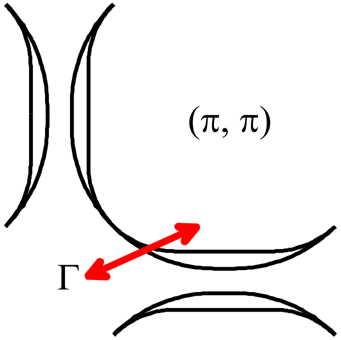


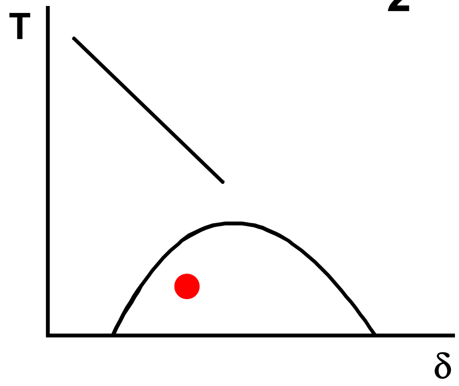
Kordyuk *PRL* 2004

Circular dichroism in nodal region

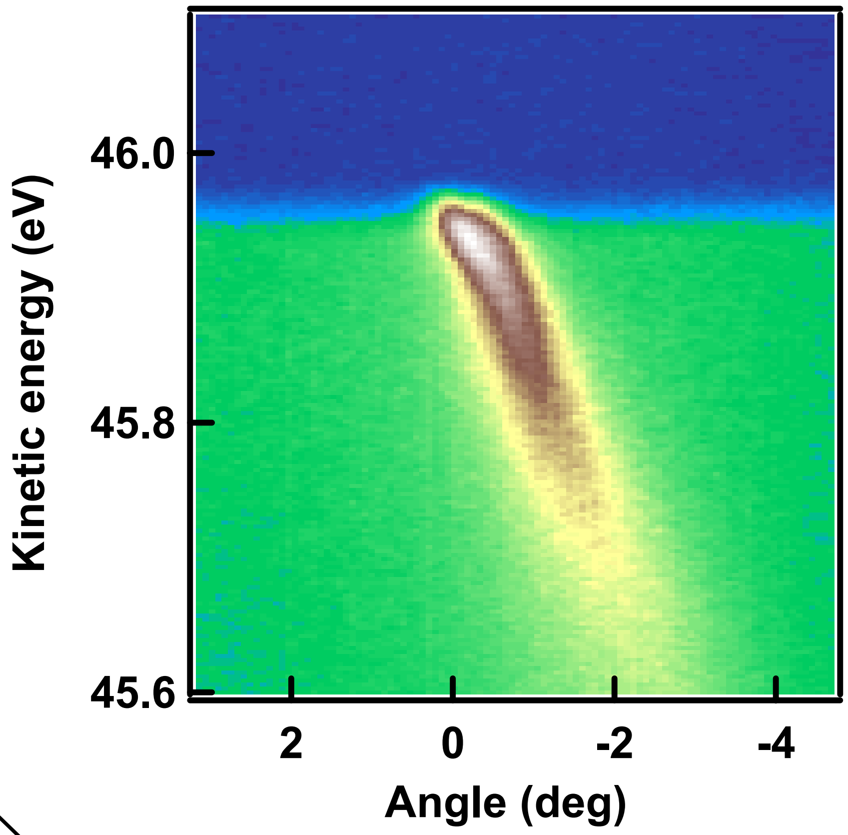


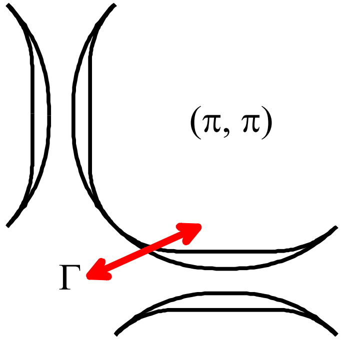


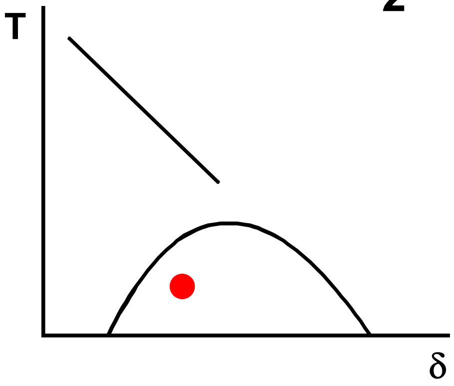




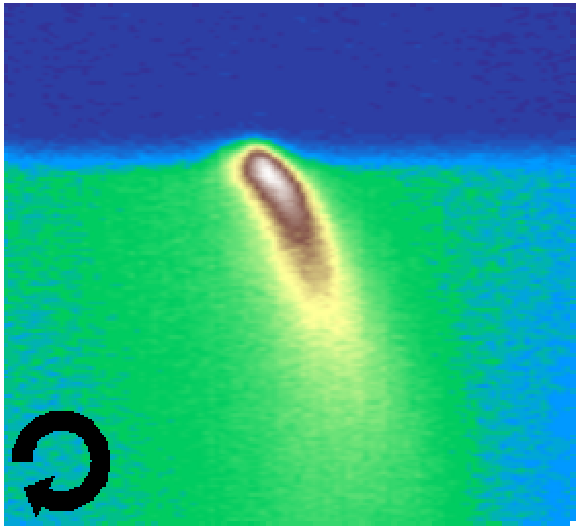
Circular dichroism in nodal region

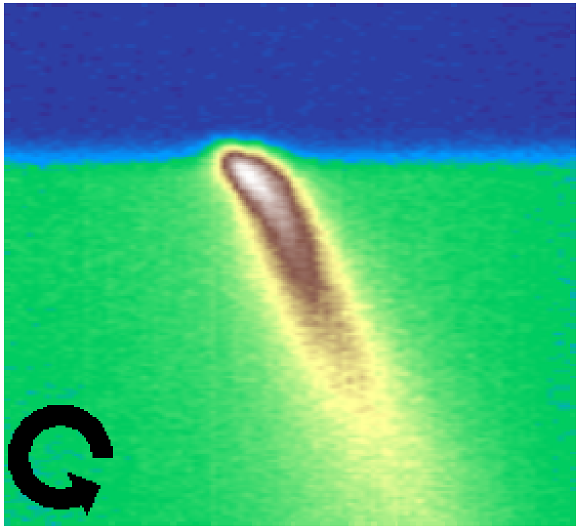


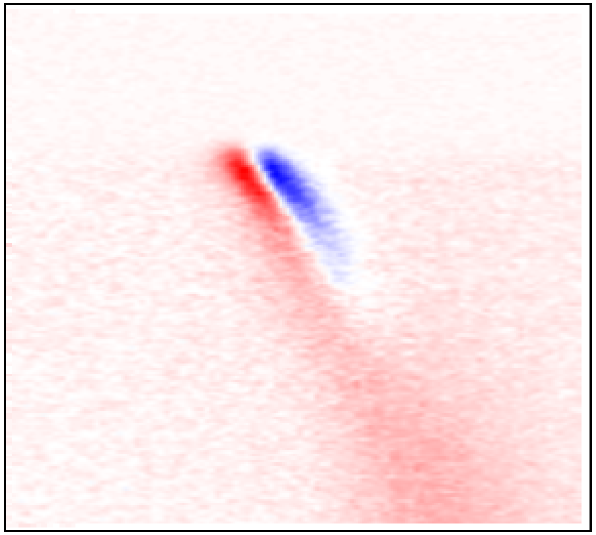


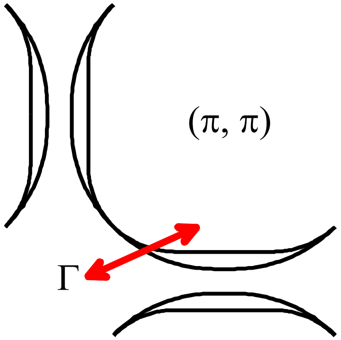


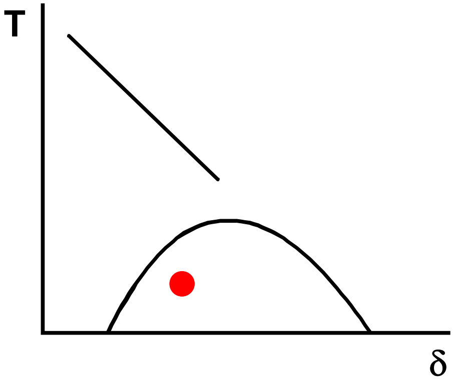
Circular dichroism in nodal region



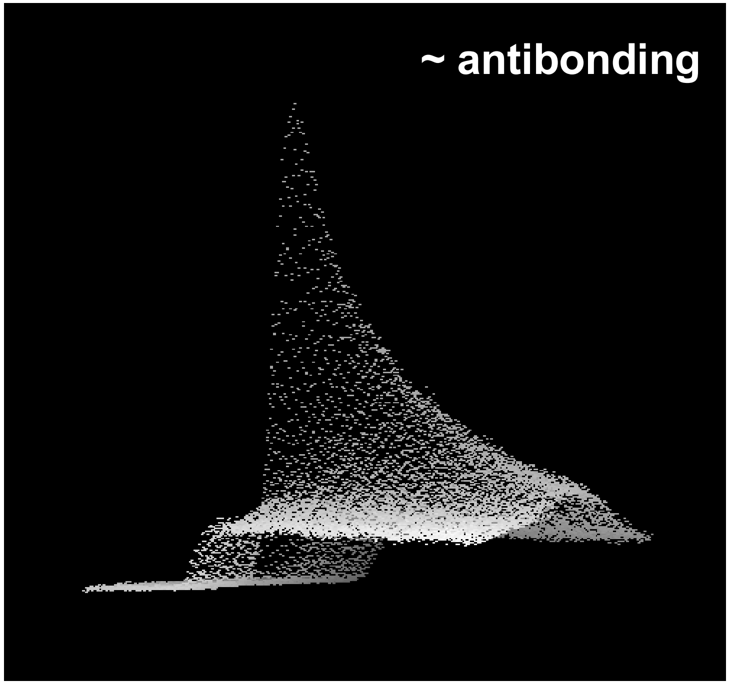


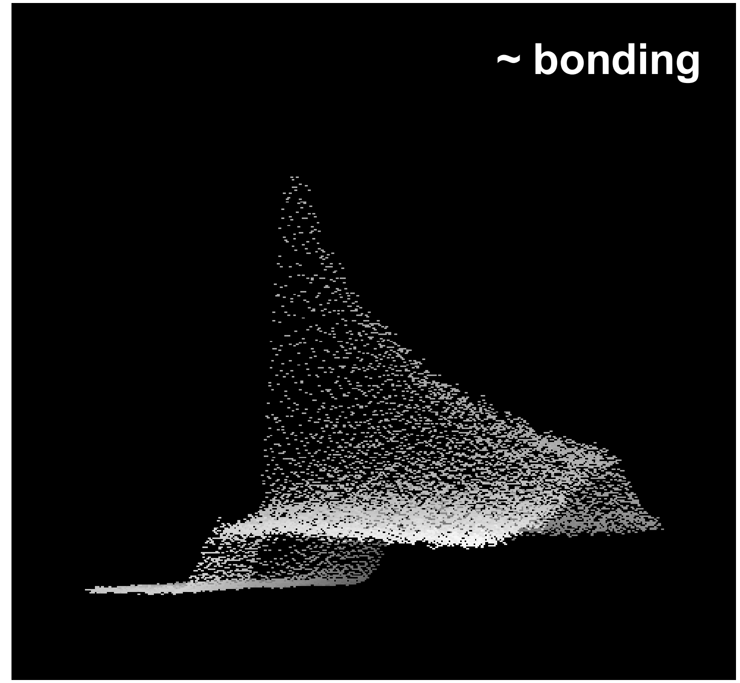


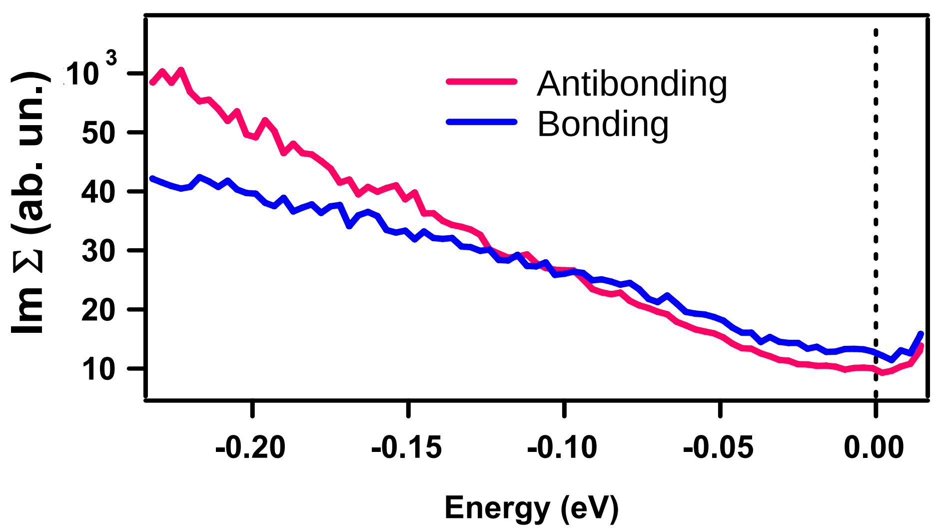




Odd scattering







Conclusions

- The spectral function analysis is applicable to the ARPES spectra from HTSC cuprates.

- Along the nodal direction well defined quasiparticles exist even for the underdoped Bi-2212 in the pseudogap state.

- Two channels in the scattering rate can be distinguished.

- The main doping independent contribution to the scattering can be well understood in terms of the conventional Fermi liquid model...

- ...while the additional doping dependent contribution has a magnetic origin.

- The magnetic contribution essentially increases with underdoping becoming dominant for the rest of the Brillouin zone and therefore determines the unusual properties of the cuprates in the superconducting and pseudo-gap phases.