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ICTP 40th Anniversary

SMR.1572 - 2

Workshop on
Novel States and Phase Transitions in Highly Correlated Matter

12 - 23 July 2004

Origin of the dominating electron-boson coupling in the HTSC cuprates as seen by ARPES

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Origin of the dominating electron-boson coupling in the HTSC cuprates as seen by ARPES

Sergey V. Borisenko

WORKSHOP ON
NOVEL STATES AND PHASE TRANSITIONS IN HIGHLY CORRELATED MATTER
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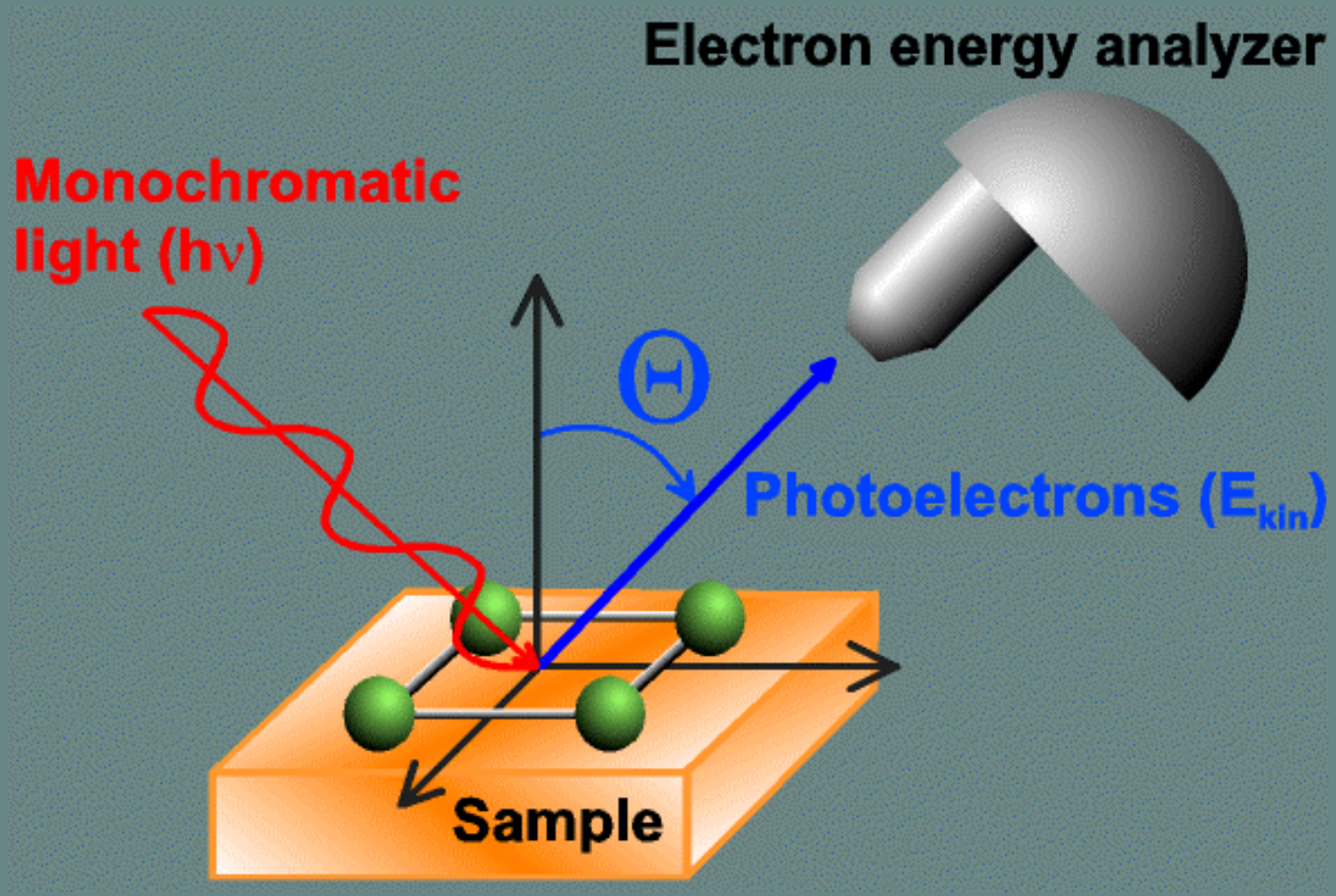
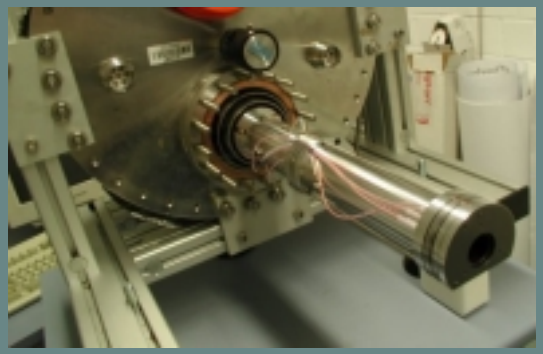
www.ifw-dresden.de/IFF/11/arpes


Electron energy analyzer
Monochromatic light (hν)
Θ
Photoelectrons (E_kin)
Sample

(k,ω)-space explorer today



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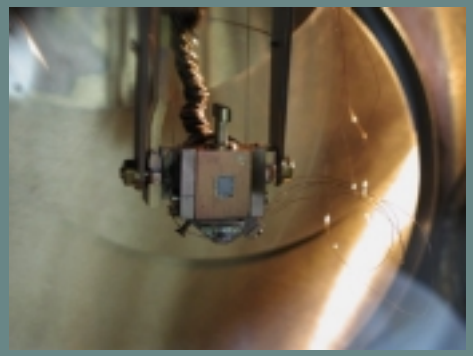

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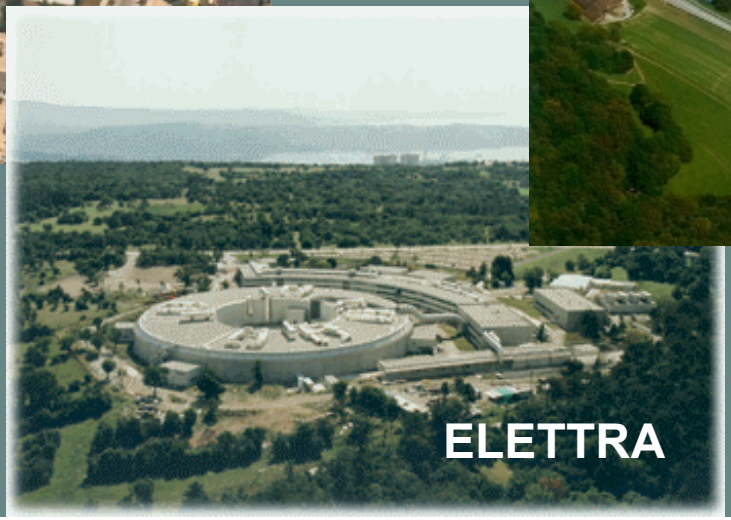


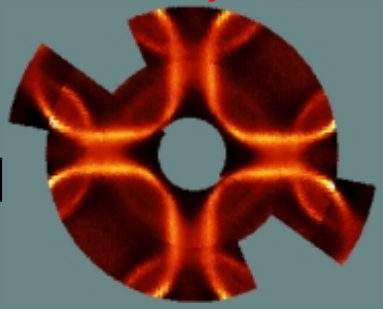
Today

$I(\mathbf{k}_x,\mathbf{k}_y,\omega)$

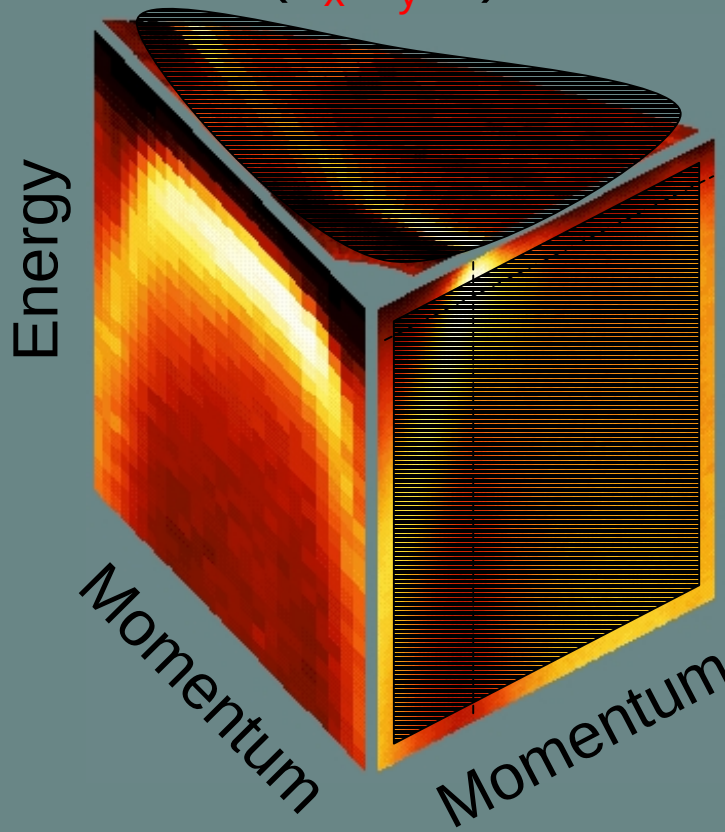
EDM

$I(\mathbf{k}_x,\mathbf{k}_y,\omega)$

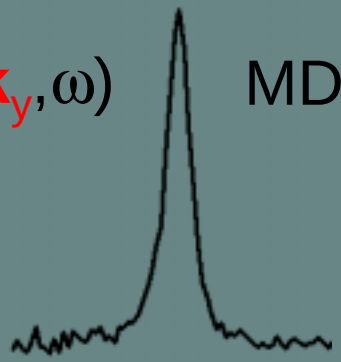
MDM



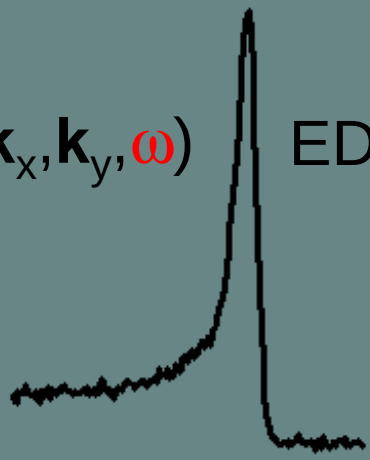
$I(\mathbf{k}_x,\mathbf{k}_y,\omega)$



$I(\mathbf{k}_x,\mathbf{k}_y,\omega)$ MDC

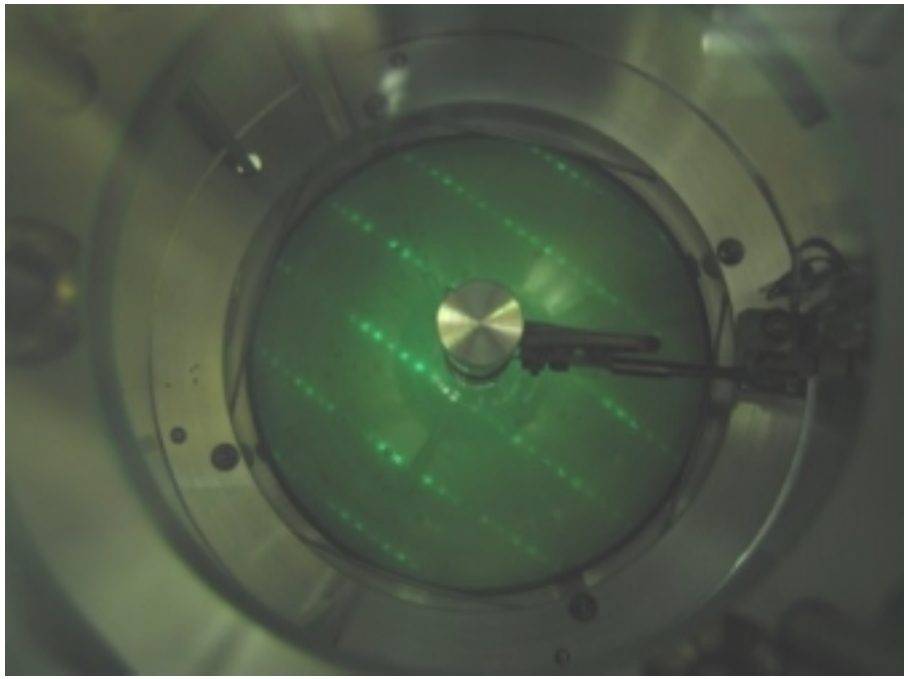


$I(\mathbf{k}_x,\mathbf{k}_y,\omega)$ EDC

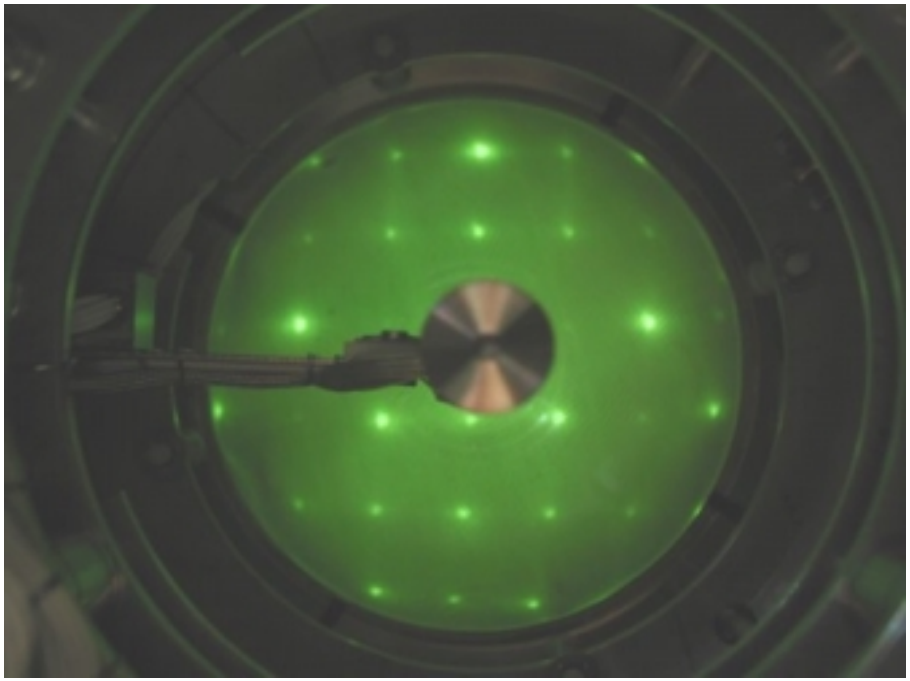


as a function of photon energy and polarisation...

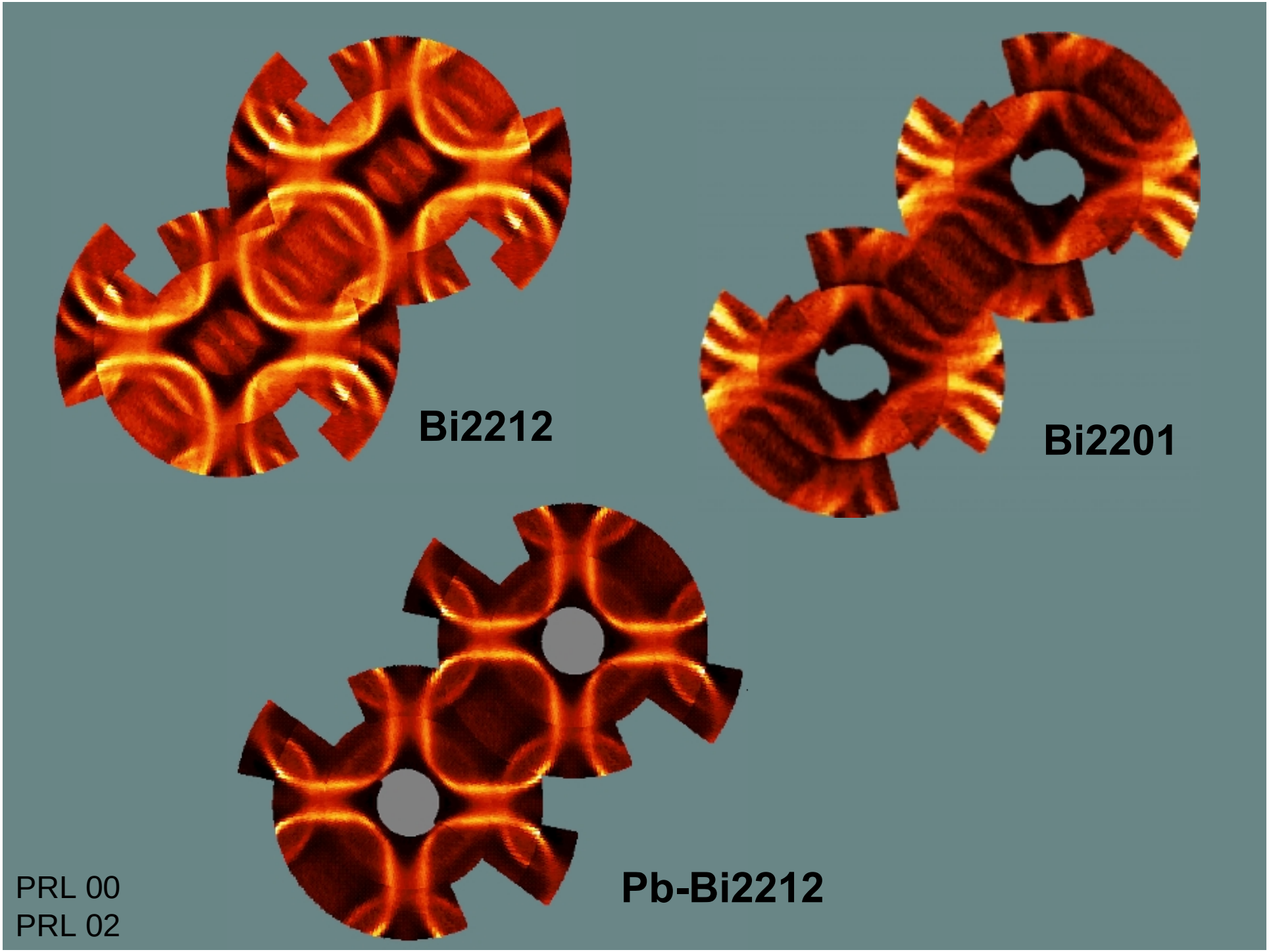
To Pb or not to Pb...



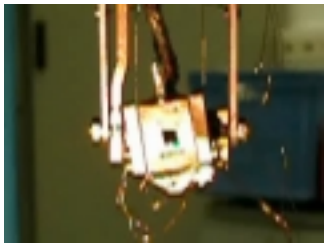
BSCCO



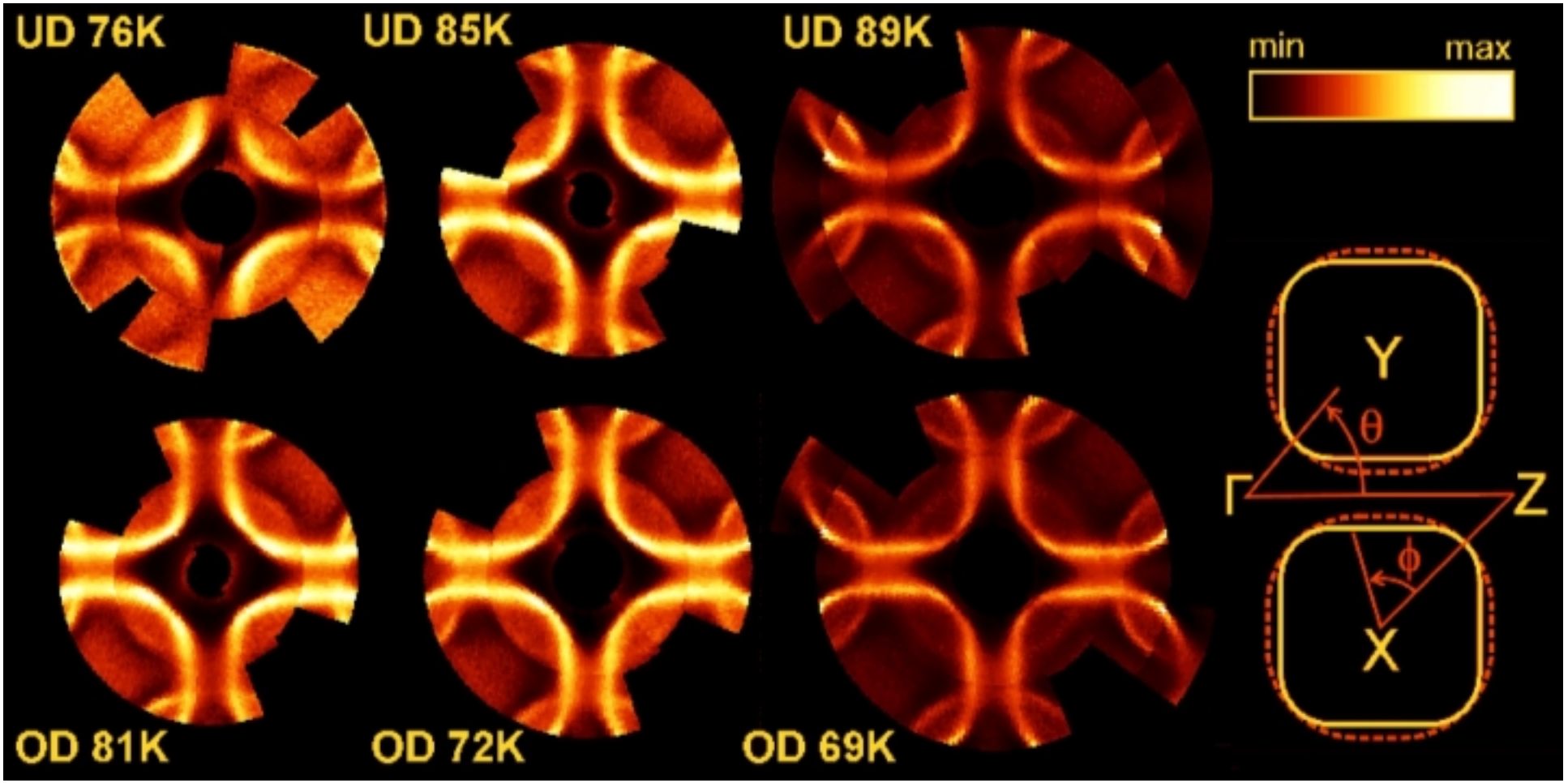
Pb-BSCCO



PRL 00
PRL 02

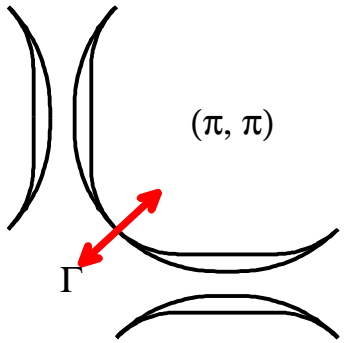


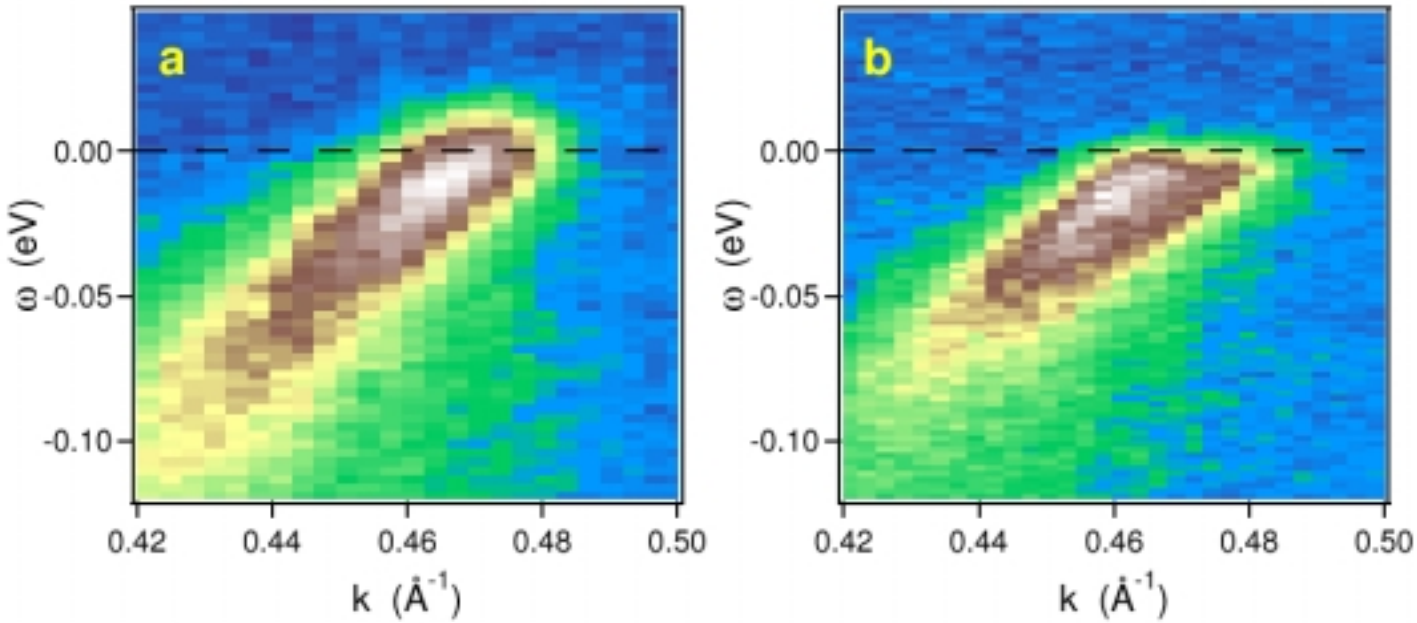
Doping dependence of the Fermi surface

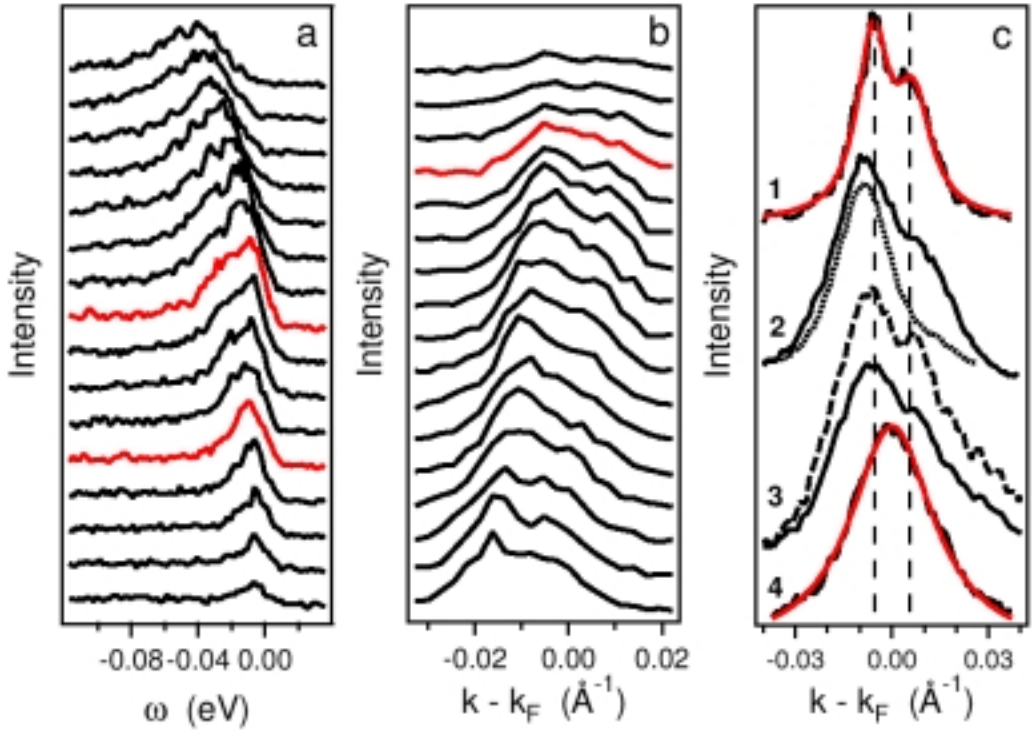


PRB 02

Bilayer splitting in the nodal direction

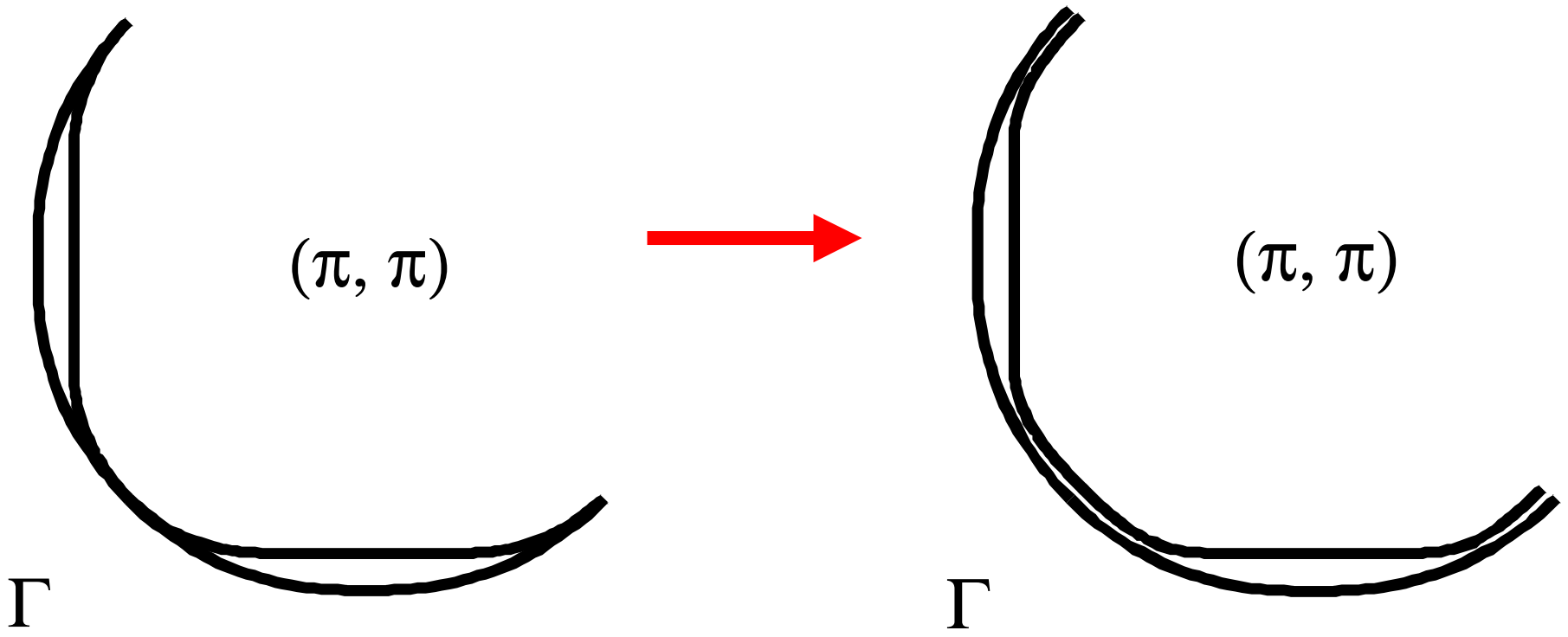




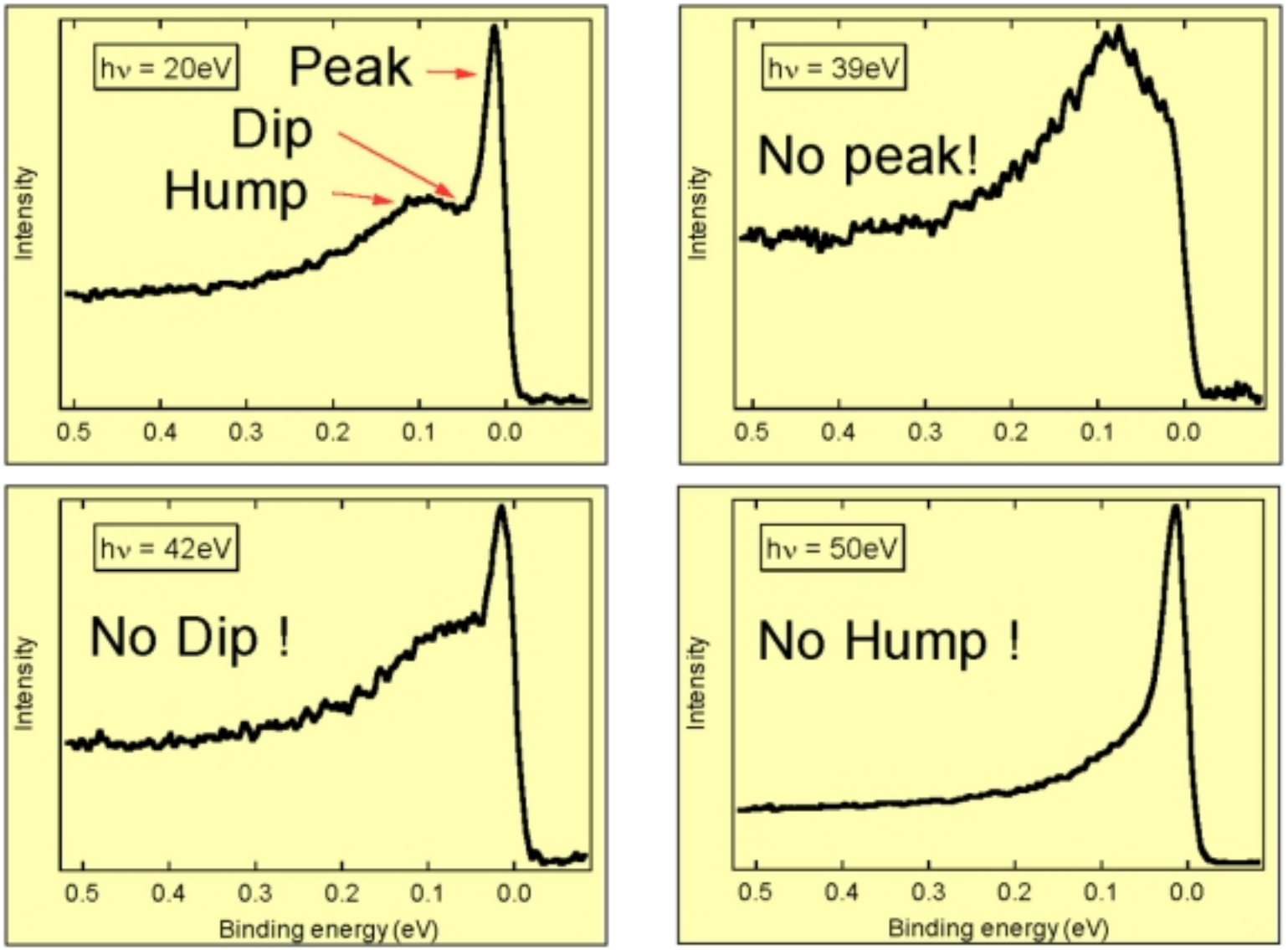


BS (node) = 0.015 Å^{-1}

cond-mat/03

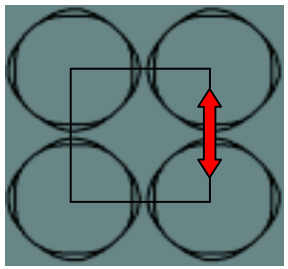

(π, π)
Γ
(π, π)
Γ

Energy dependence of the peak-dip-hump spectra

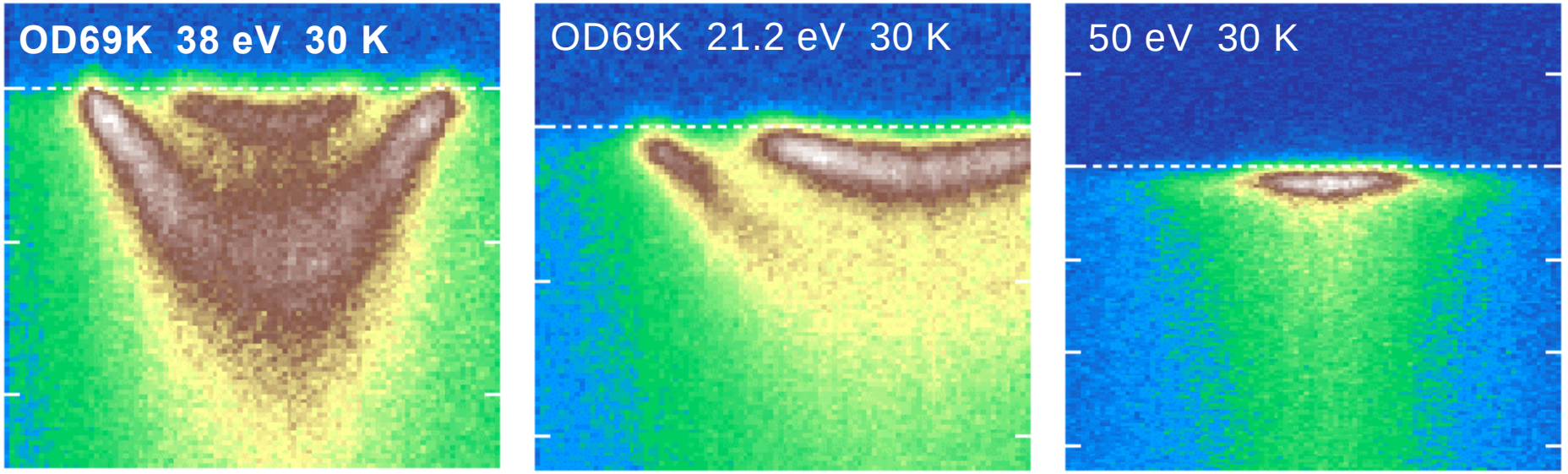


superconducting state, (π,0)-point spectra

PRL02



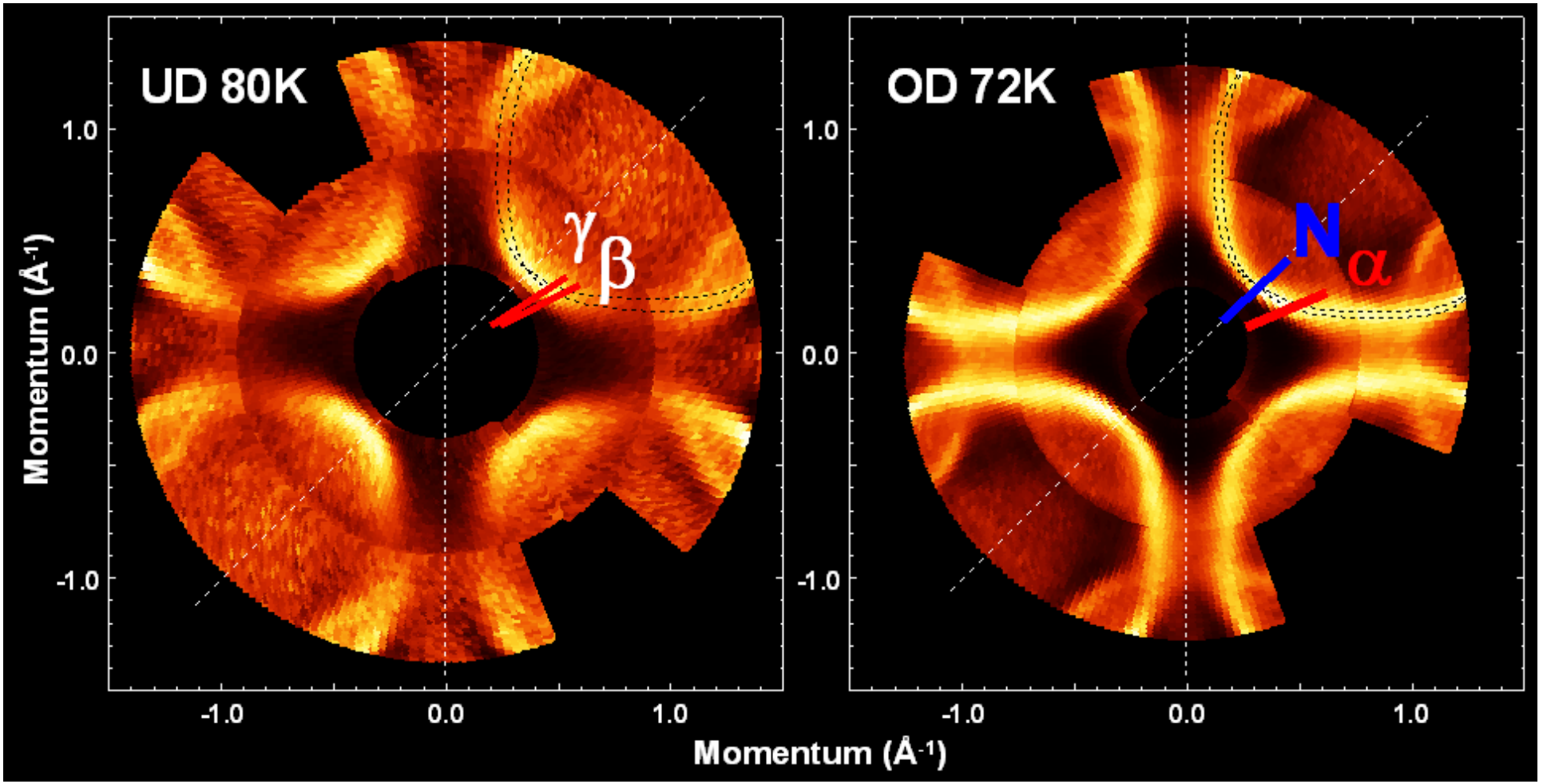
Photon energy can be used to tune the bonding/antibonding ratio



$M_{bonding}$ / $M_{antibonding}$

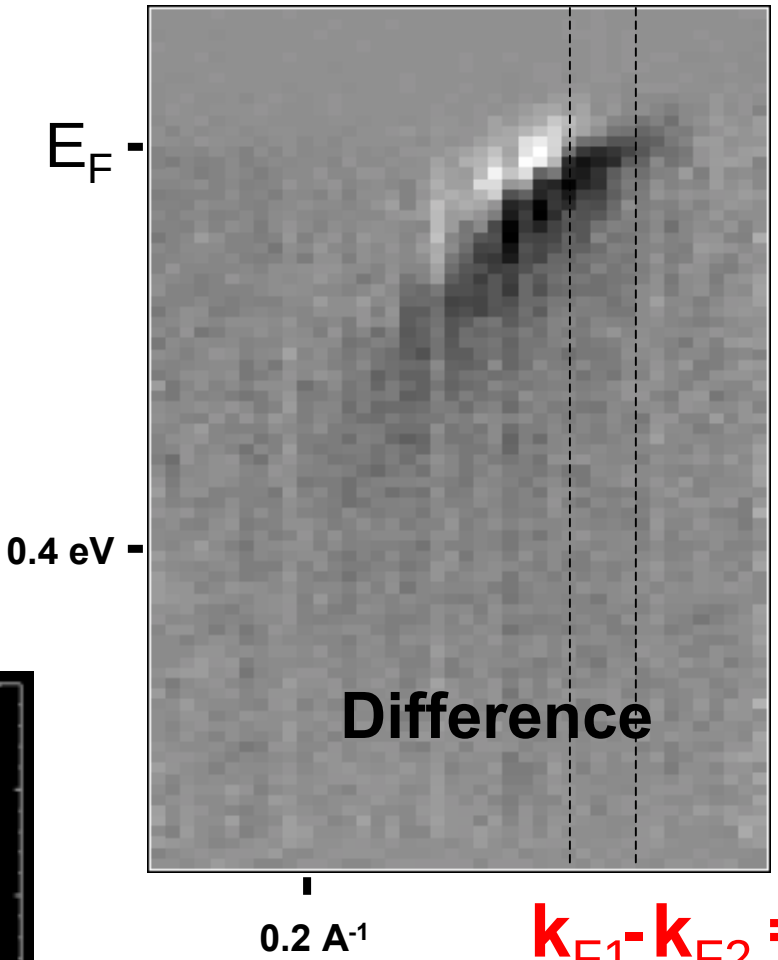
Peak-Dip-Hump structure of the (π, 0)-spectrum in overdoped case is due to the bilayer splitting

PRL 03

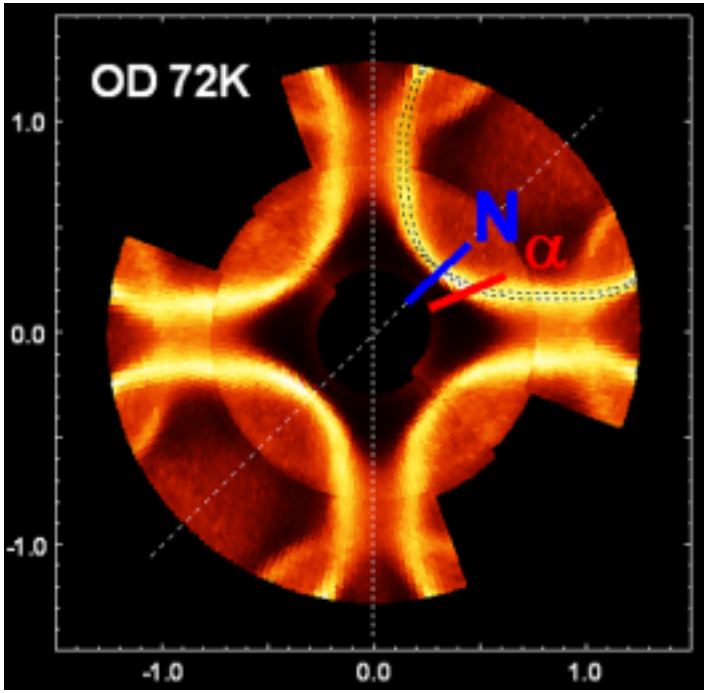


PRB(R) 04 (in press)

α

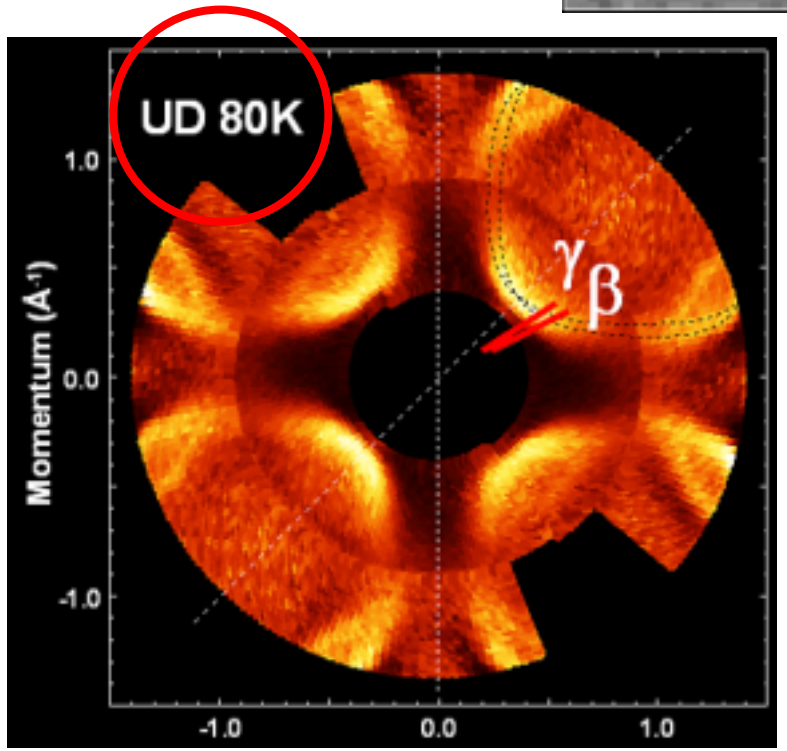


>10%



k_{F1}-k_{F2} = Bilayer Splitting

PRB(R) 04 (in press)



E_F

γ

0.4 eV

k_{F1} k_{F2}

Bilayer splitting

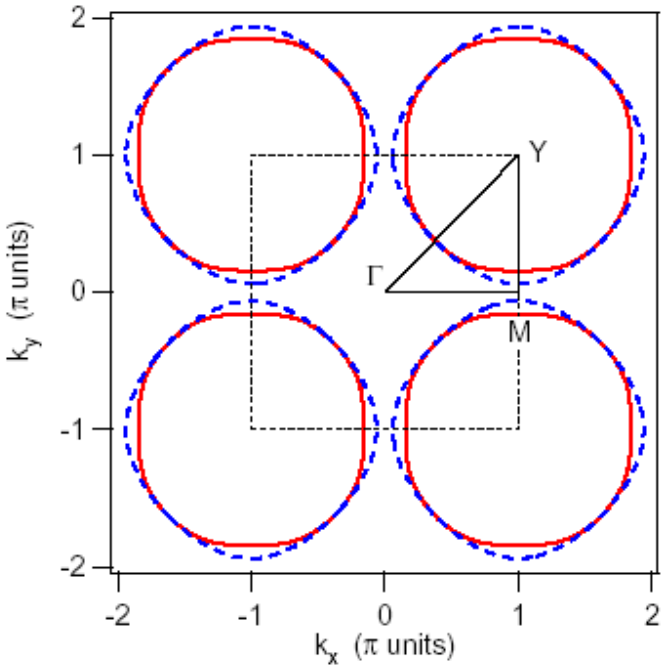
E_F

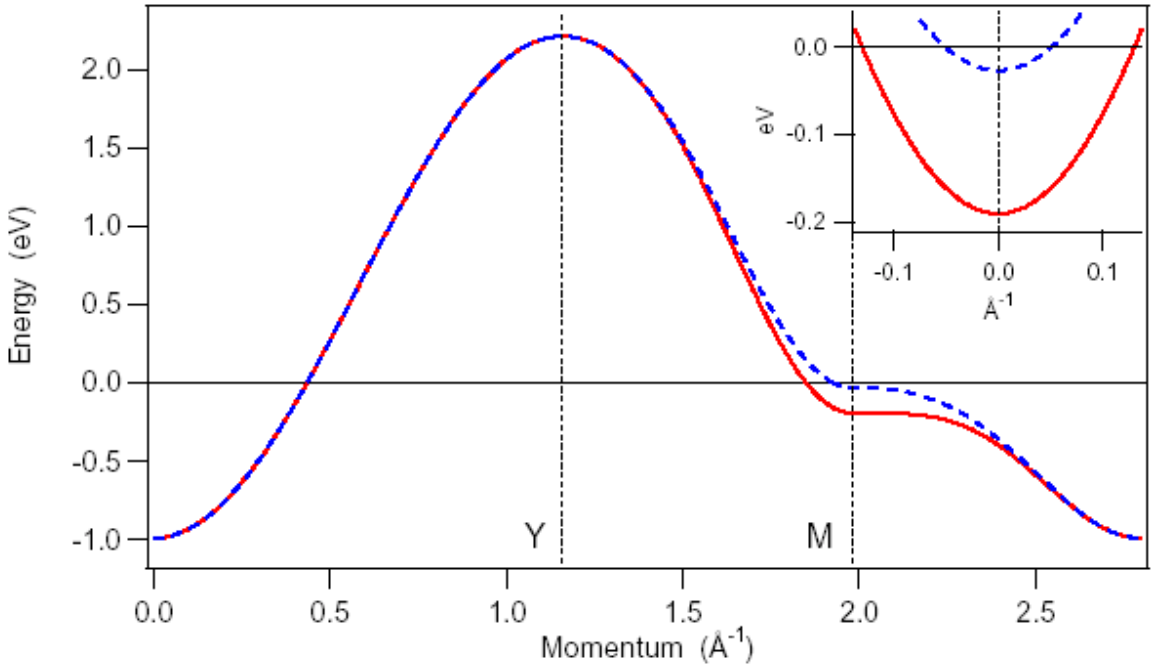
β

0.4 eV

k_{F1} k_{F2}

TB parameters

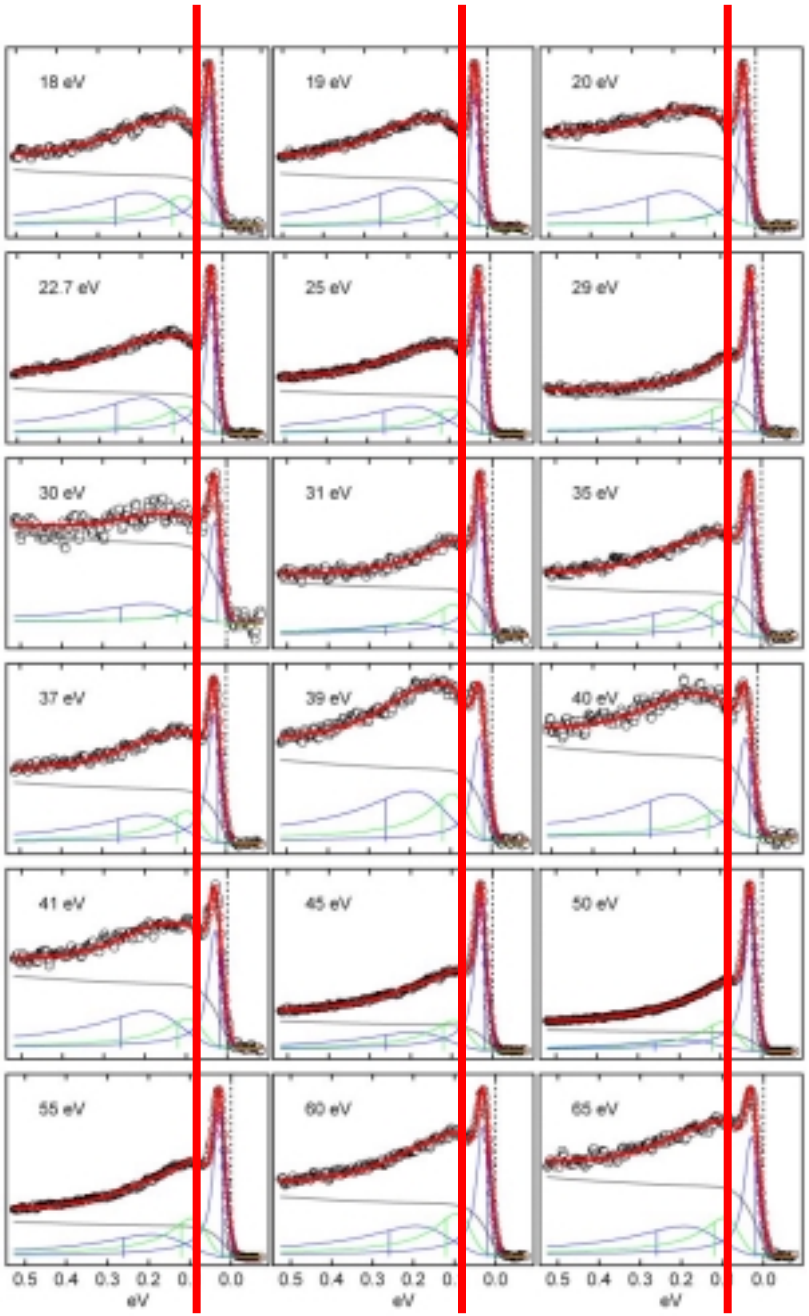


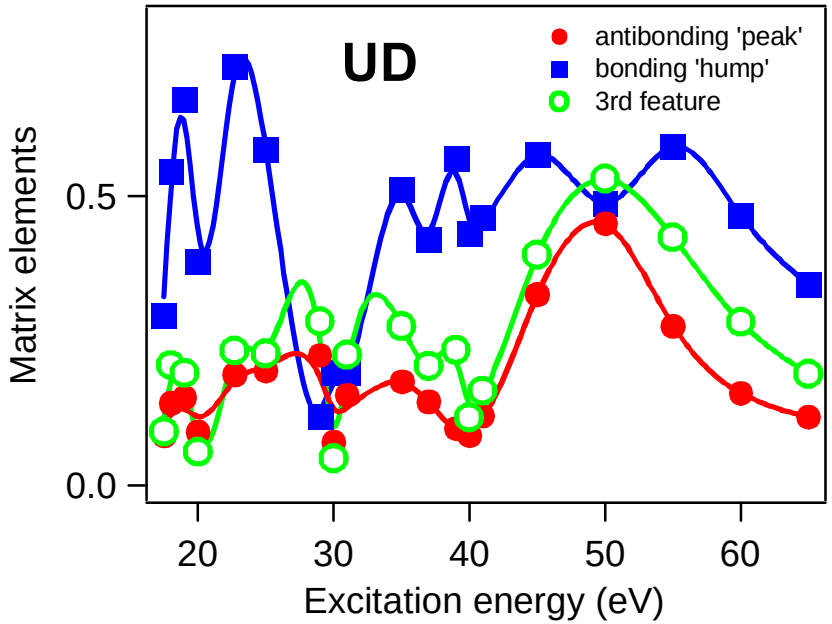


Sample	t (eV)	t' (eV)	t'' (eV)	$t_\perp$ (eV)	$\Delta\epsilon$ (eV)
OD 69 K	0.40	0.090	0.045	0.082	0.43
UD 77 K	0.39	0.078	0.039	0.082	0.29

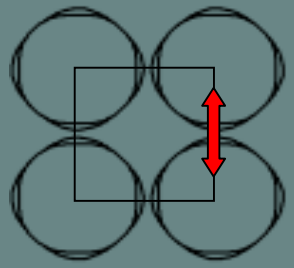
PRB03

Photon energy dependence of the (π, 0)-spectra in UD sample

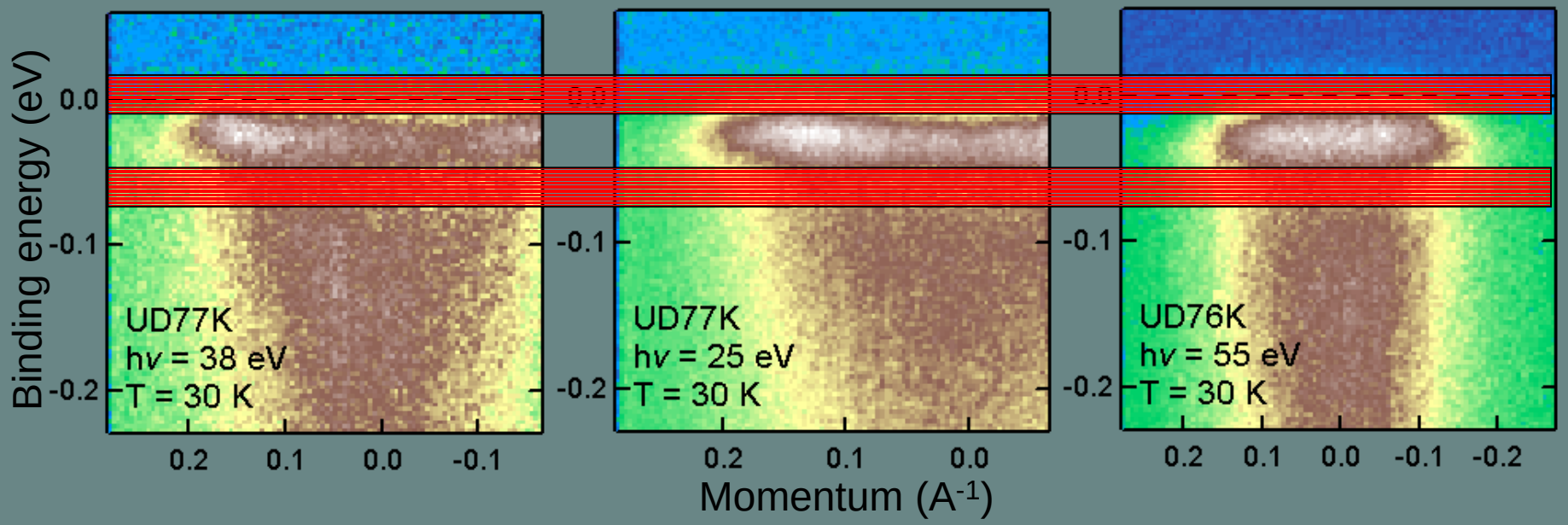




PRL 03



Where are the bonding and antibonding bands?



$M_{bonding} / M_{antibonding}$

?

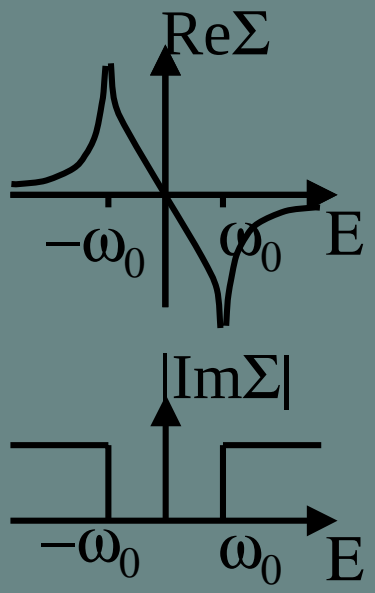
?

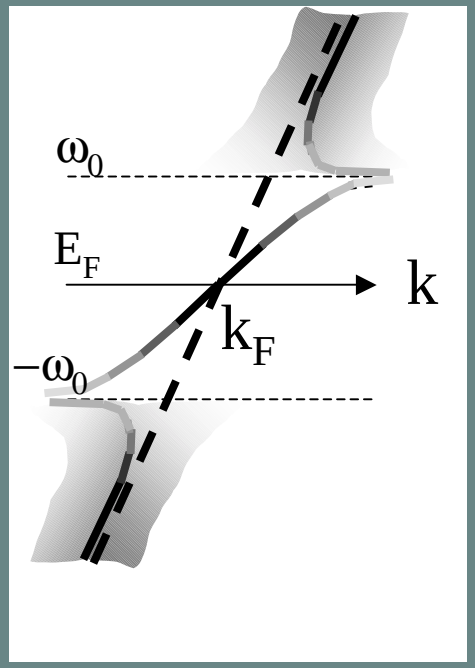
PRL 03

Coupling to a collective mode

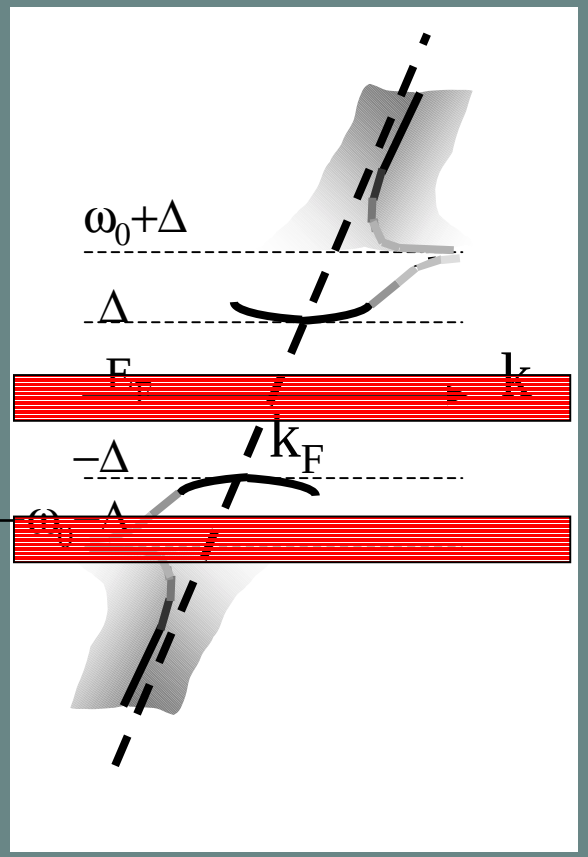
normal state

superconducting state



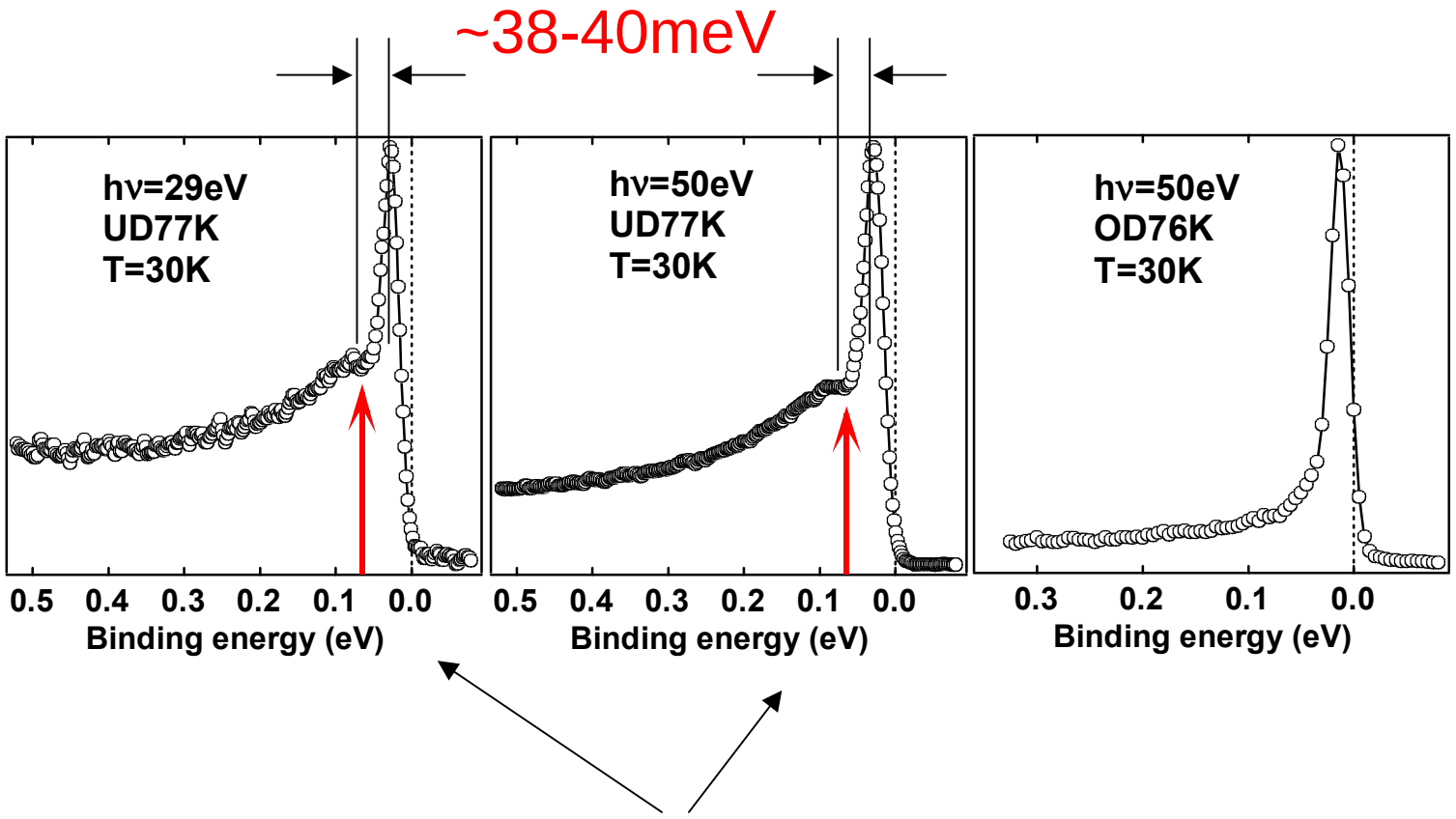


$\lambda = -\delta \mathrm{Re}\Sigma/\delta E|_{EF}$



For E< $|\omega_0|$ - only virtual excitations
renormalization $1+\lambda$

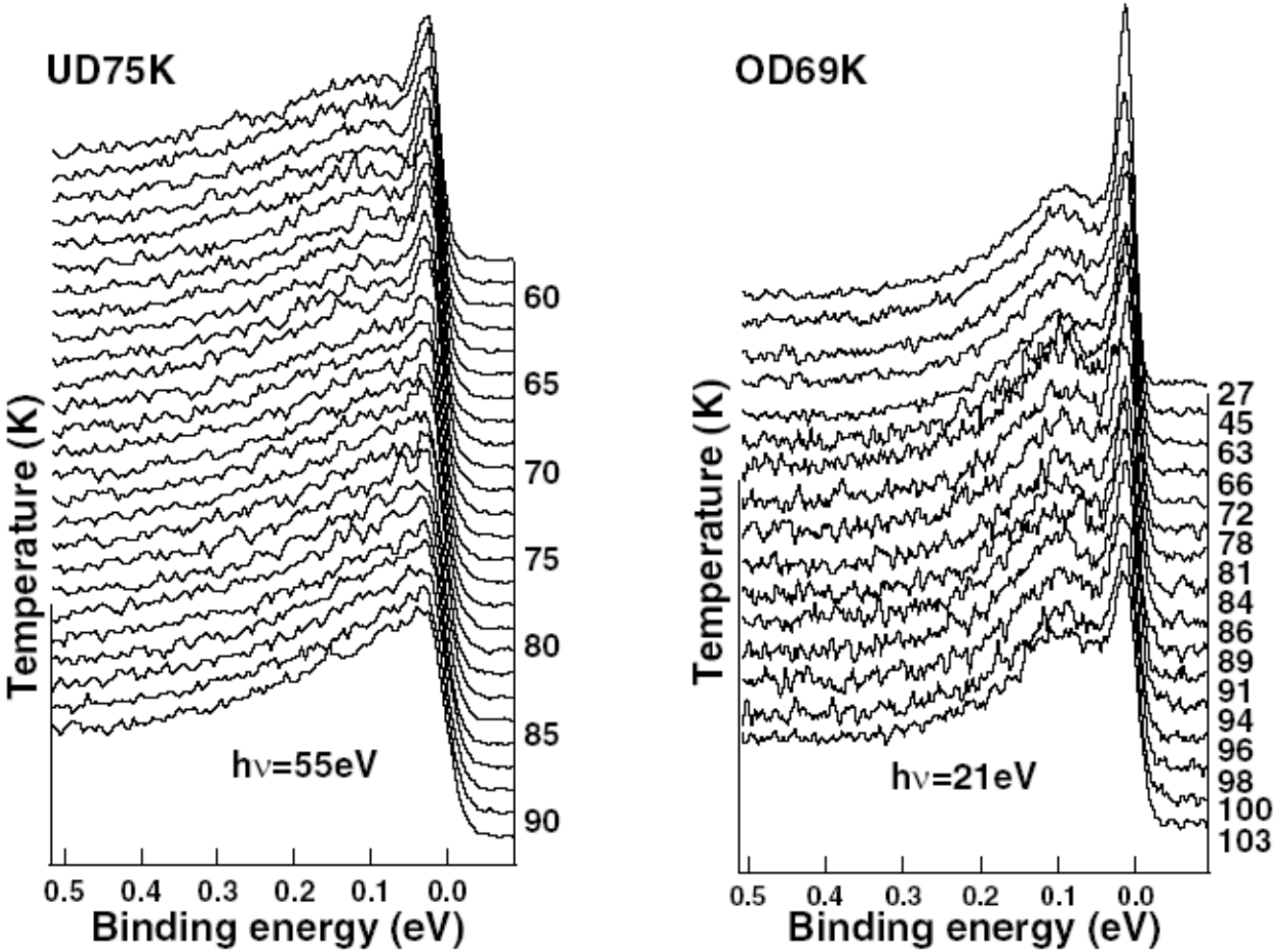
At these photon energies the contribution of the bonding band into the total spectral weight is negligible



this is an intrinsic anomaly !

PRL03

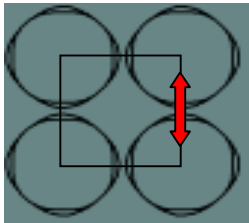
Temperature dependence



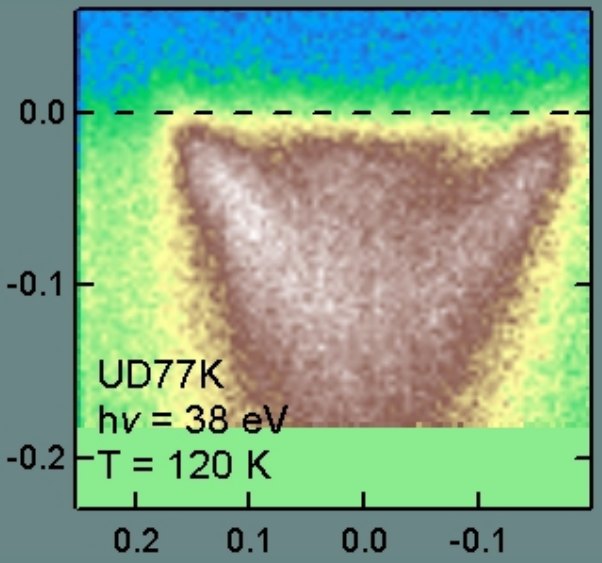
intrinsic effects

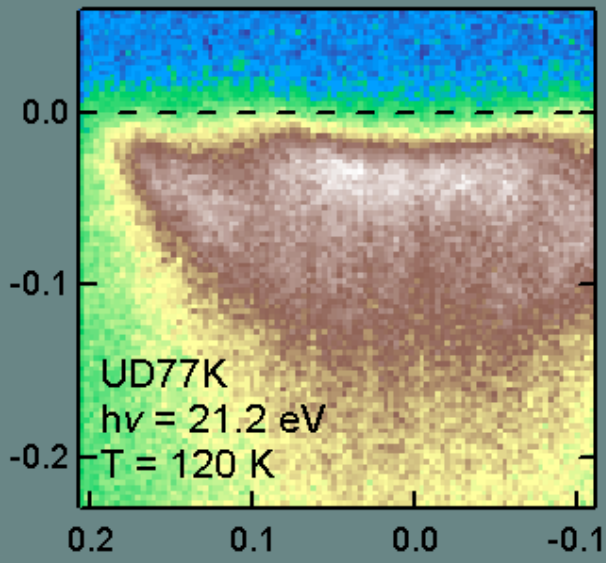
bilayer splitting

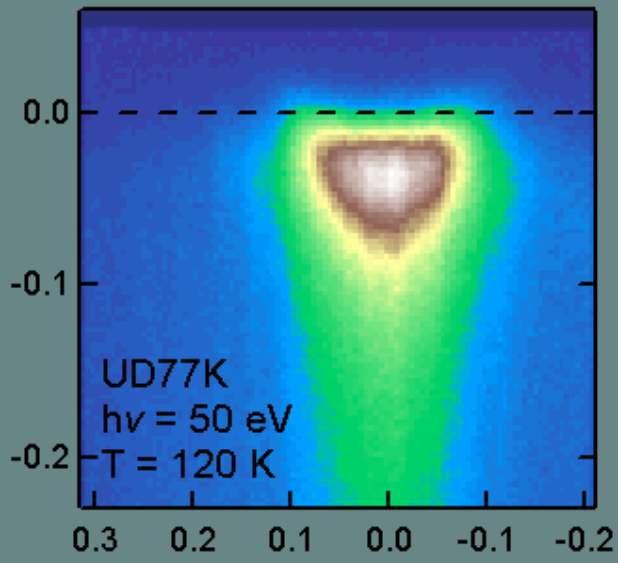
PRL03

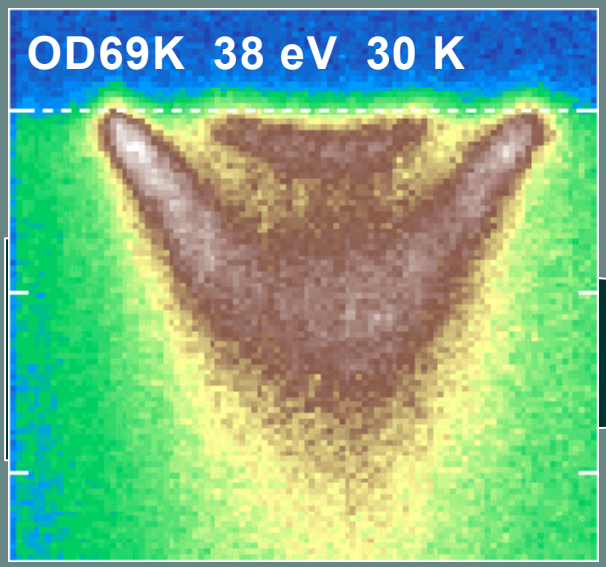


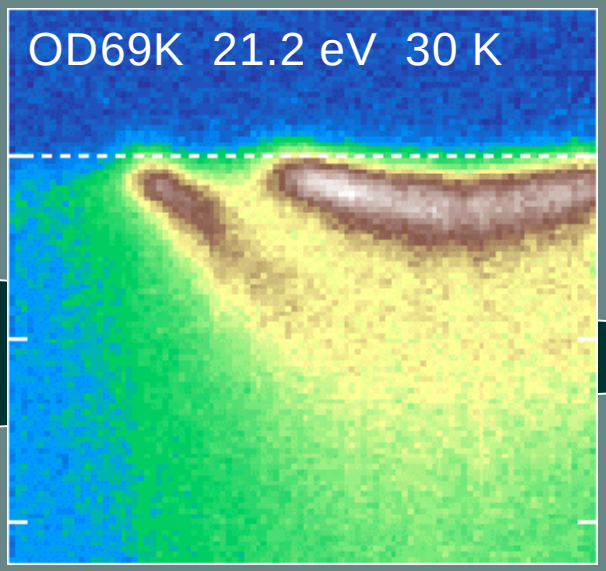
$T>T_C$: no more depletion of the spectral weight at $\Delta+\omega_0$ energy, bilayer splitting is resolved

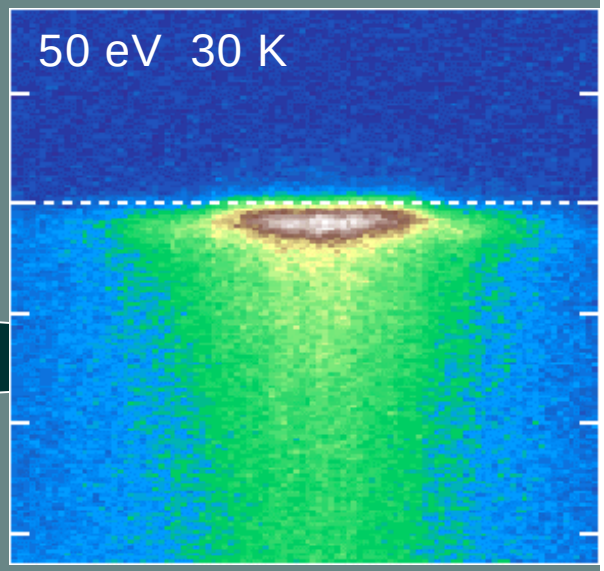






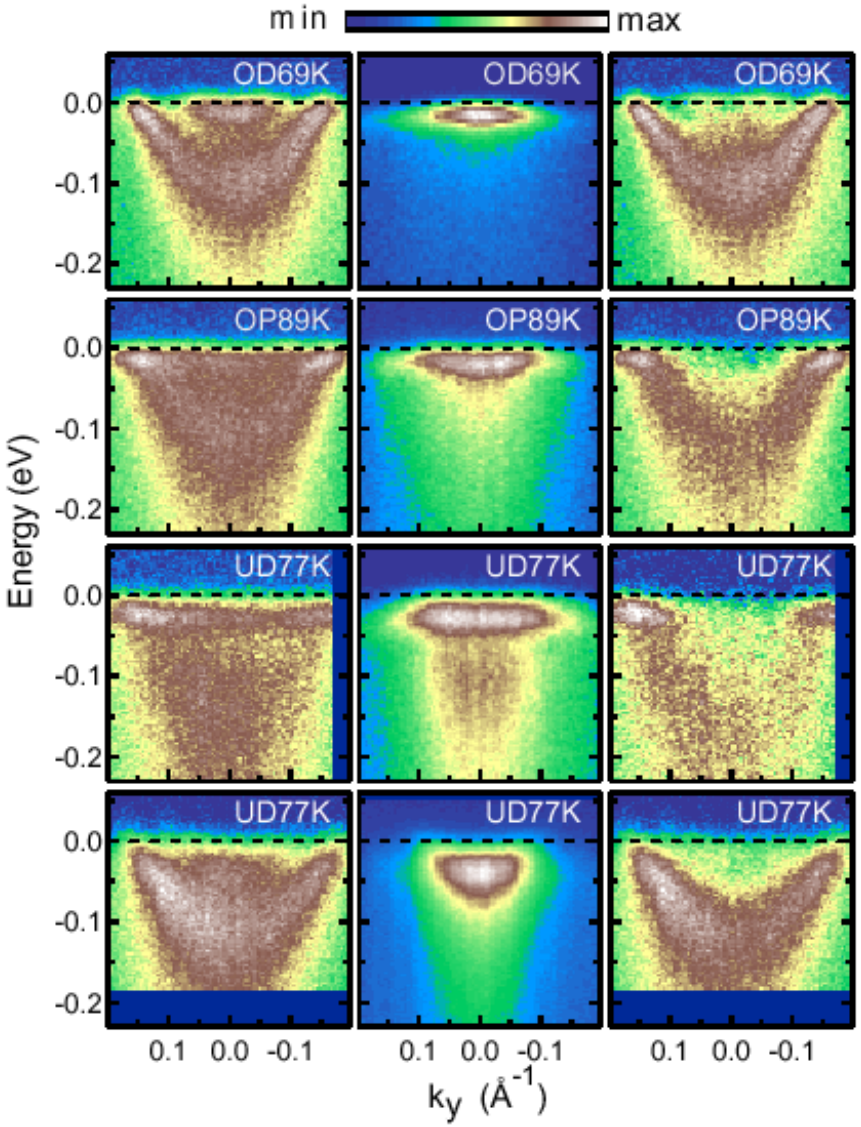


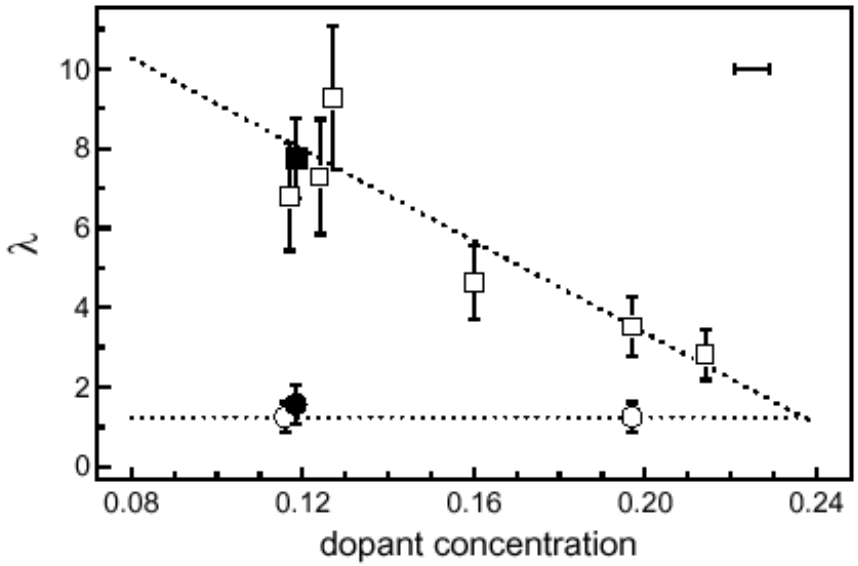




PRL03

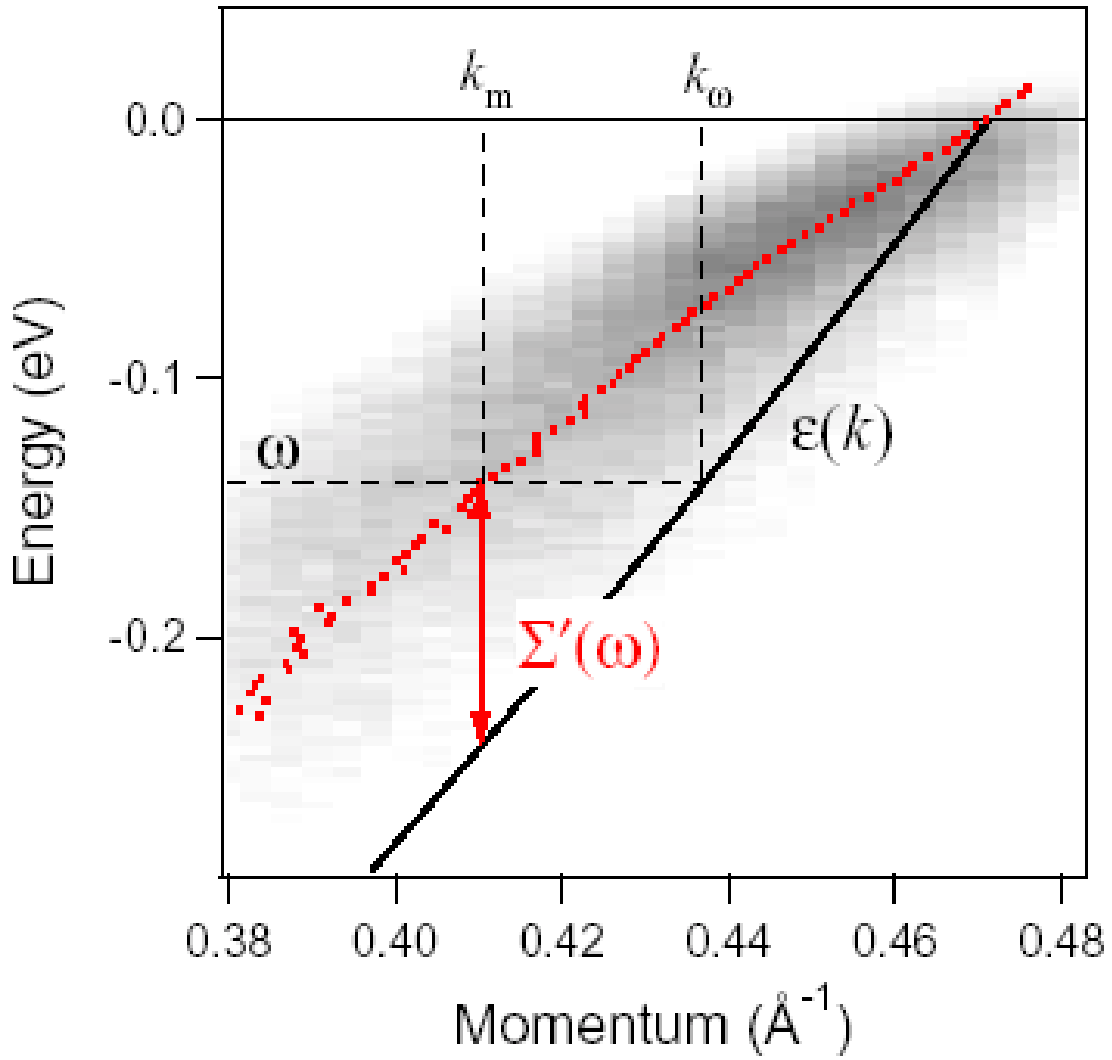
Elimination of the antibonding band and estimation of the coupling strength





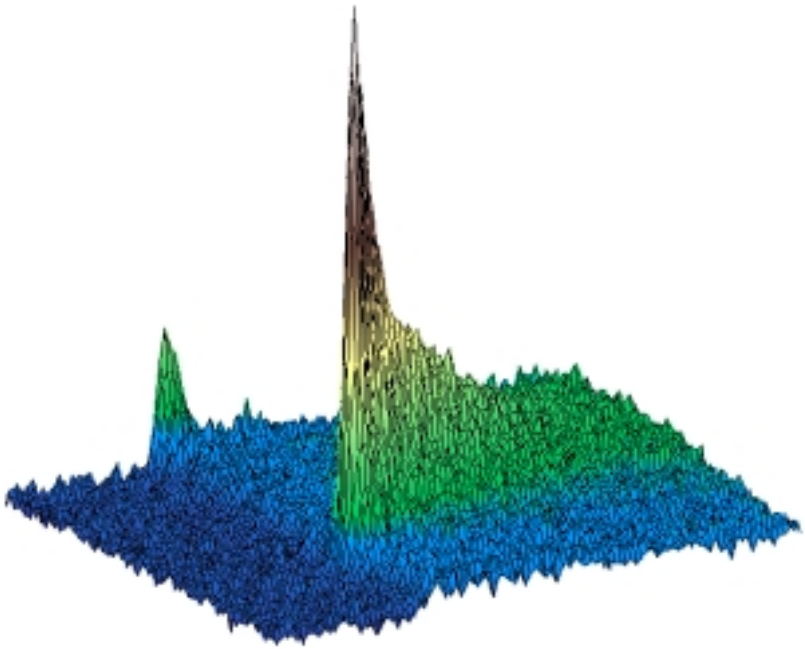
PRL03

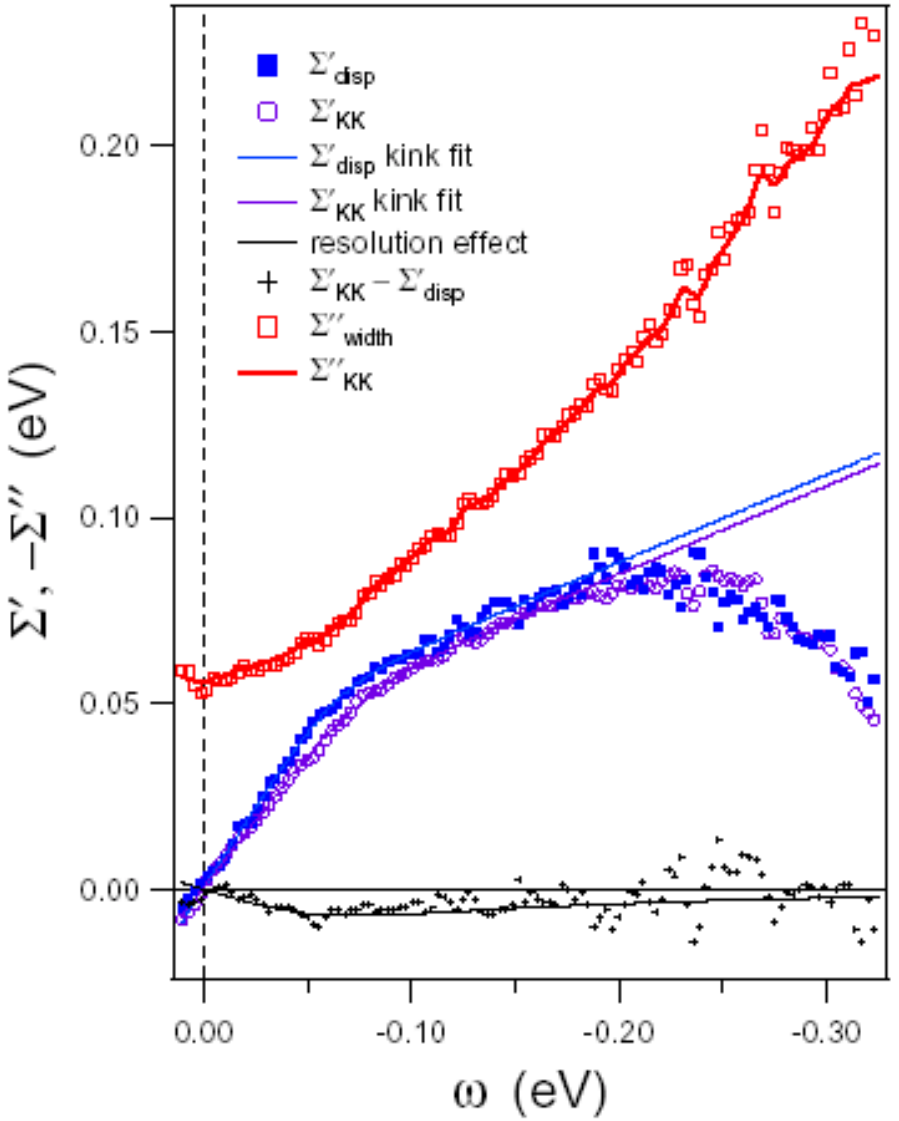
Electron self-energy from the photoemission spectra



cond-mat/04

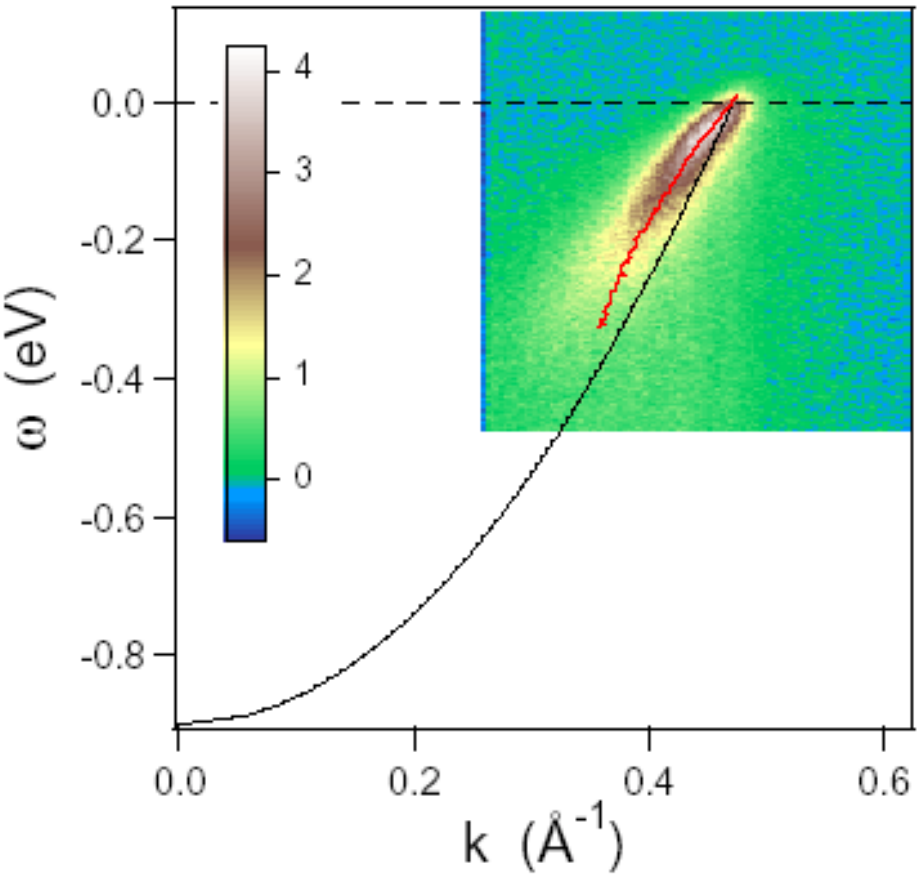
Kramers-Kronig self-consistency



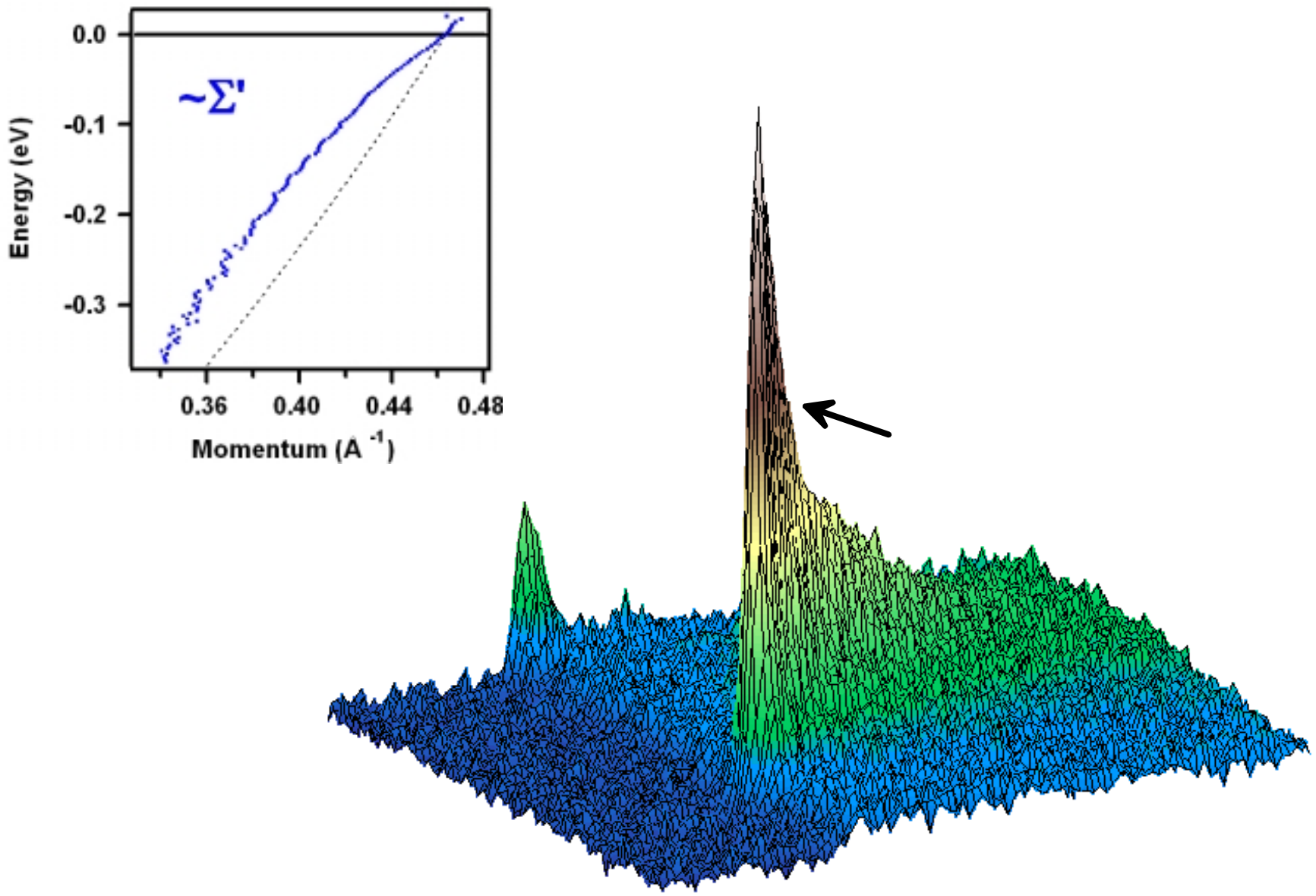


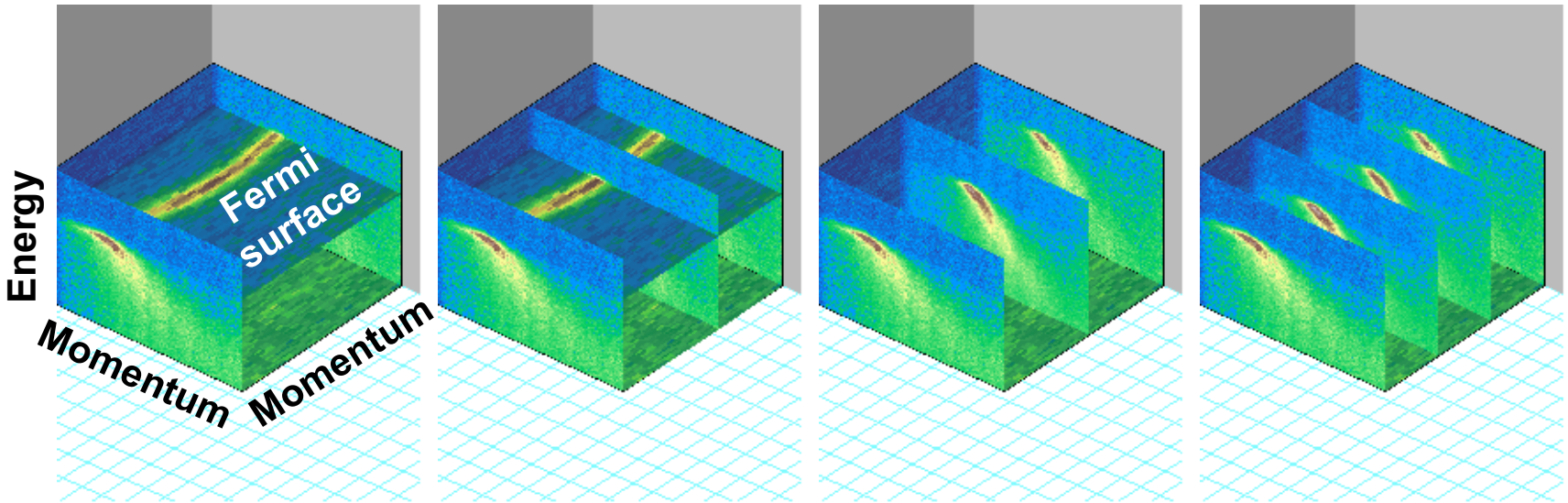
cond-mat/04

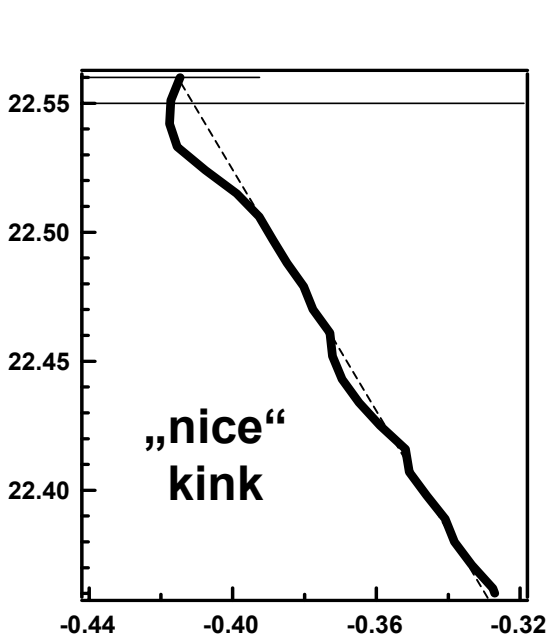
Bare electron dispersion from photoemission

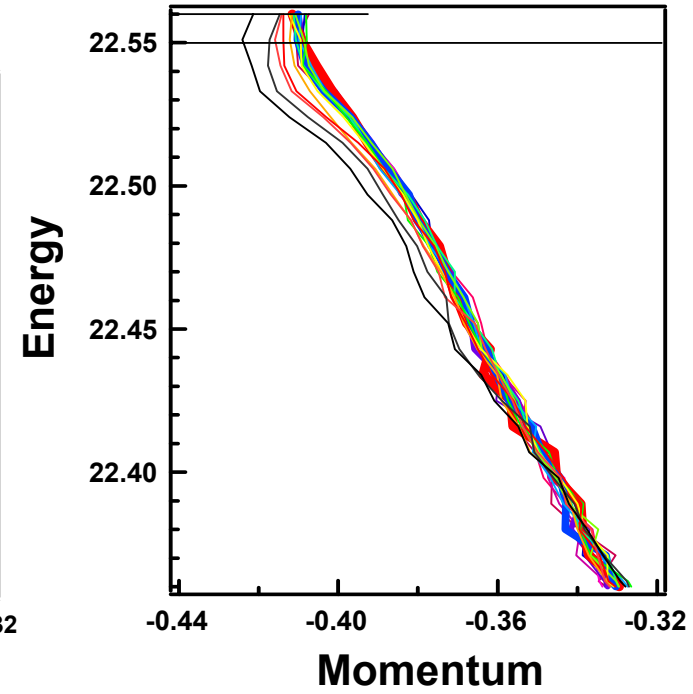


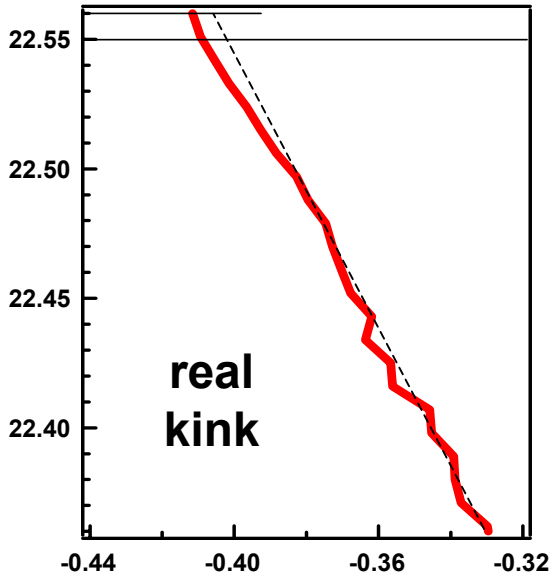
cond-mat/04


0.0
-0.1
-0.2
-0.3
Energy (eV)
~Σ'
0.36
0.40
0.44
0.48
Momentum (A -1)

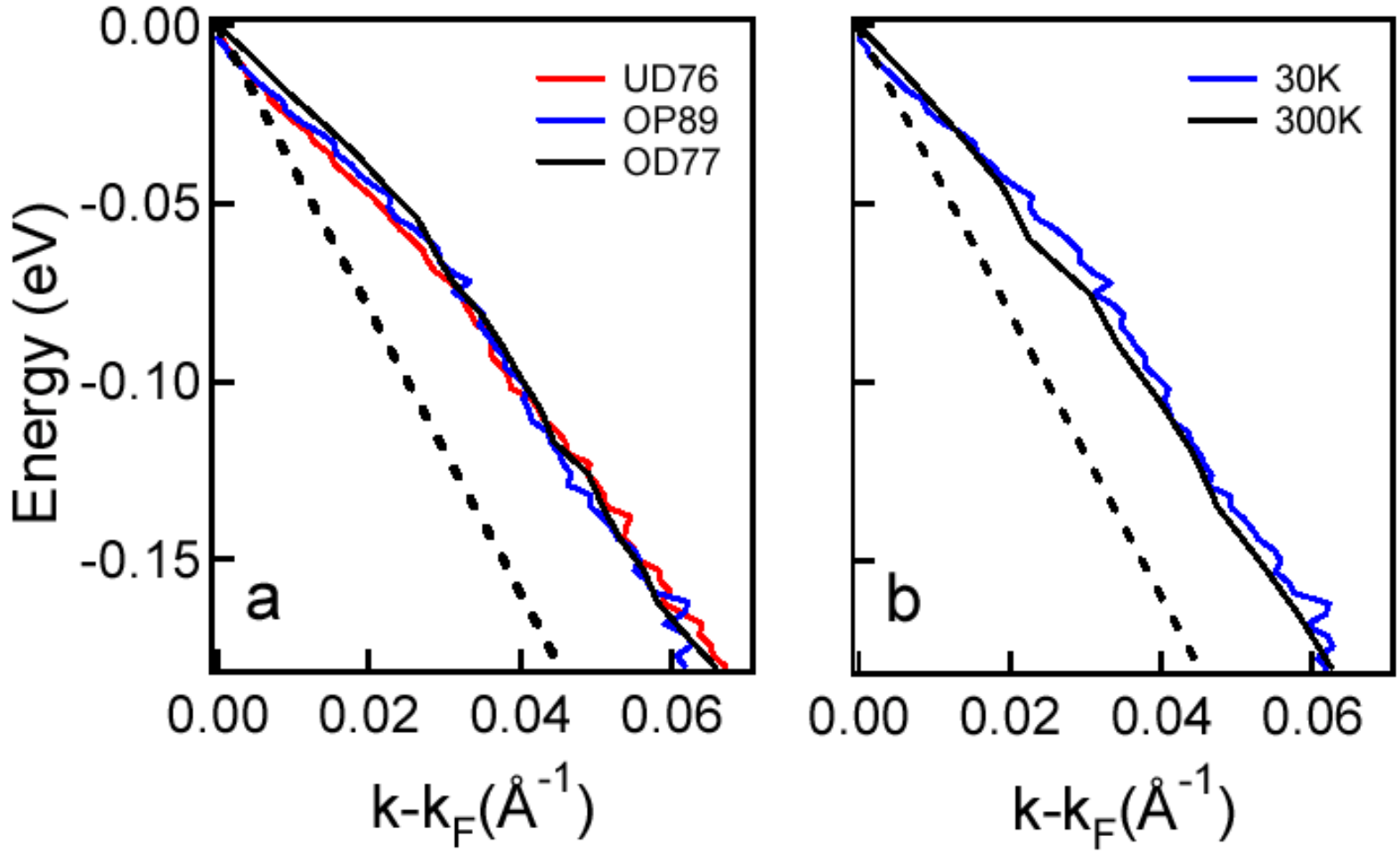

Energy
Fermi surface
Momentum
Momentum


22.55
22.50
22.45
22.40
„nice“ kink
-0.44
-0.40
-0.36
-0.32

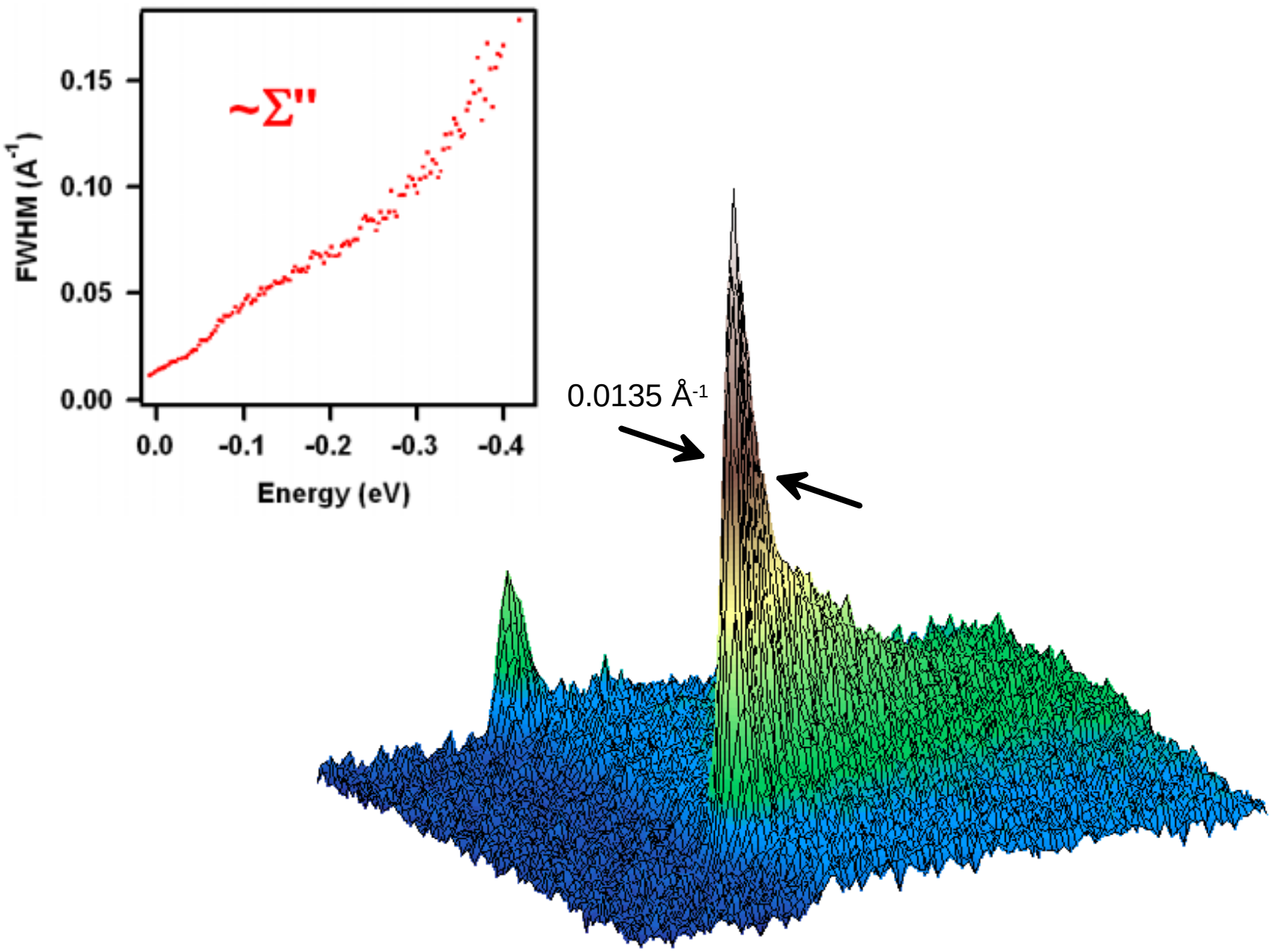

Energy
22.55
22.50
22.45
22.40
-0.44
-0.40
-0.36
-0.32
Momentum


22.55
22.50
22.45
22.40
real kink
-0.44
-0.40
-0.36
-0.32

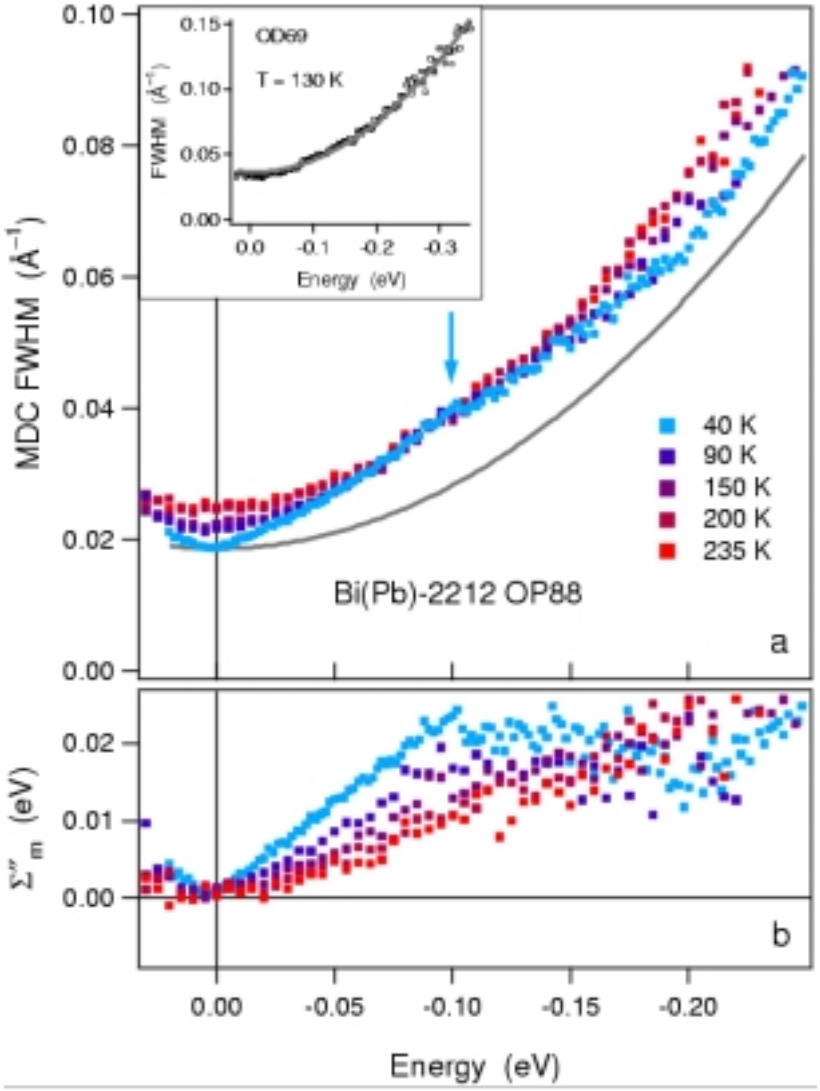
Kink in dispersion

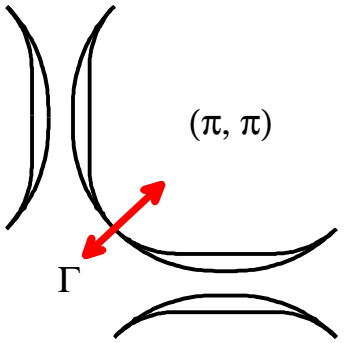


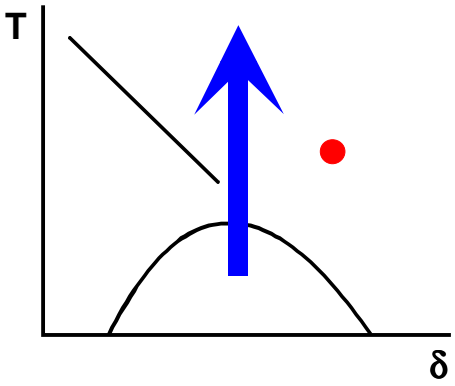
PRB (R) 04


~Σ''
FWHM (A-1)
0.15
0.10
0.05
0.00
0.0
-0.1
-0.2
-0.3
-0.4
Energy (eV)
0.0135 Å-1

"Lifetime kink"

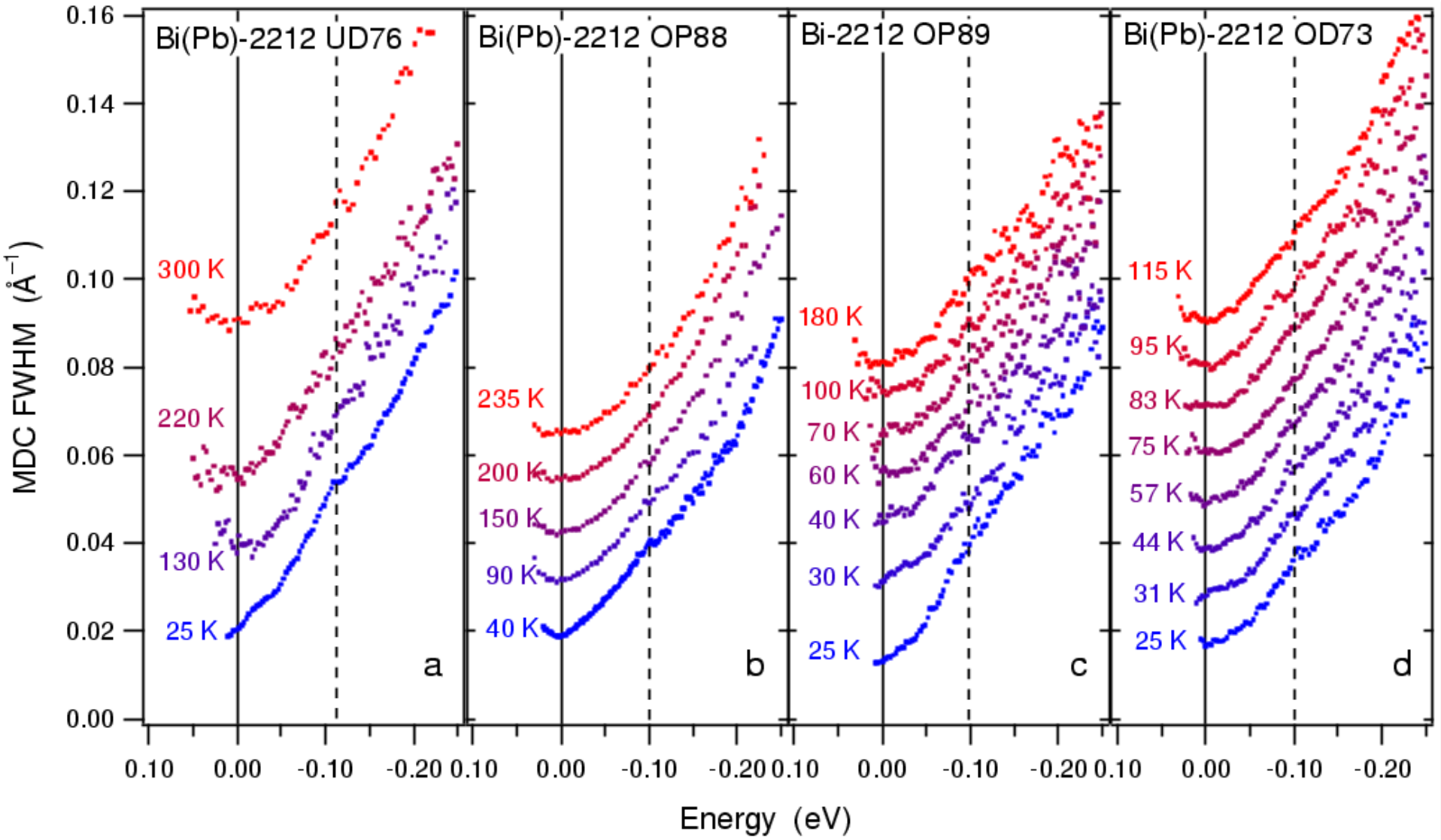






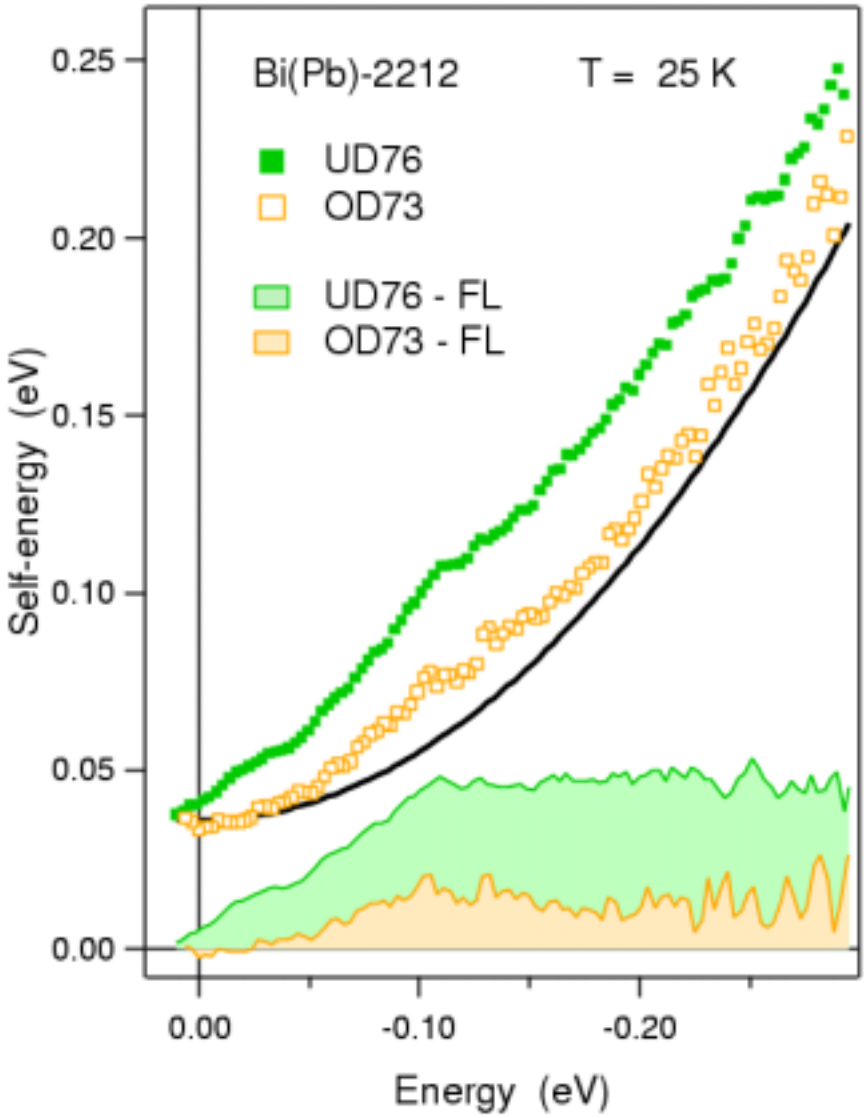
PRL04 (in press)

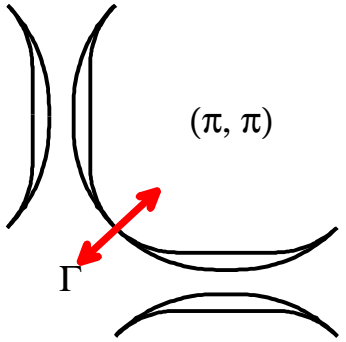
Doping and temperature dependence of the "lifetime kink"

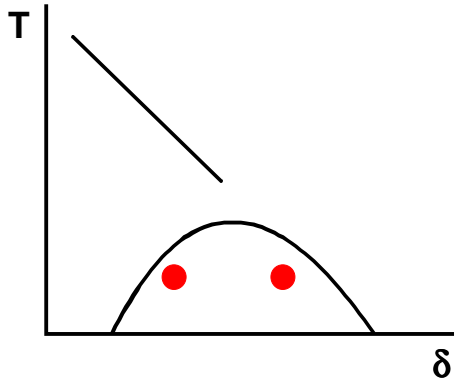


PRL04 (in press)

Coupling strength







PRL04 (in press)

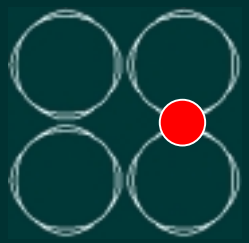
Electrons couple to ...

Energy ~ 40-100 meV

Doping dependence: UD↑
OD↓

Temperature dependence: $<T_c$ ☑
$>T_c$ ☒

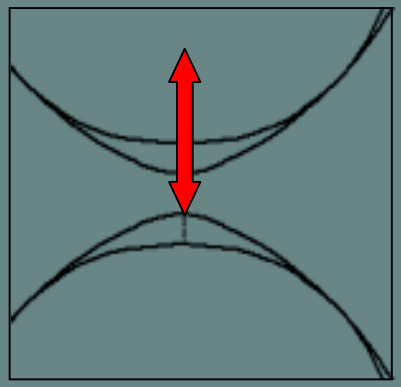
k-dependence:

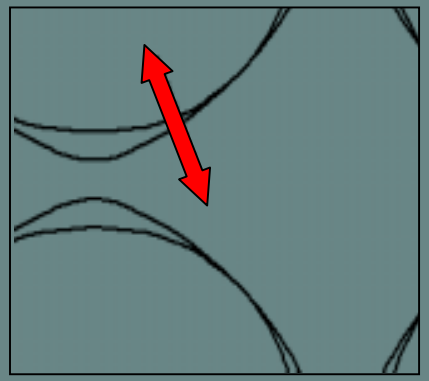


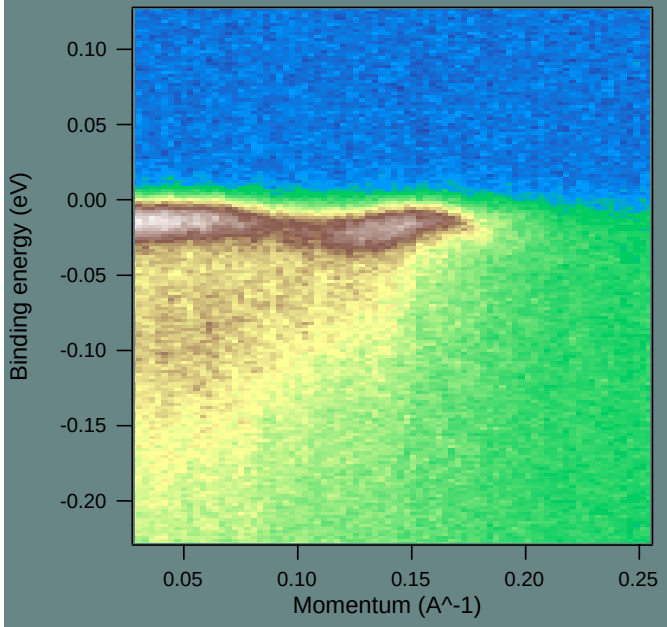
Parity: odd

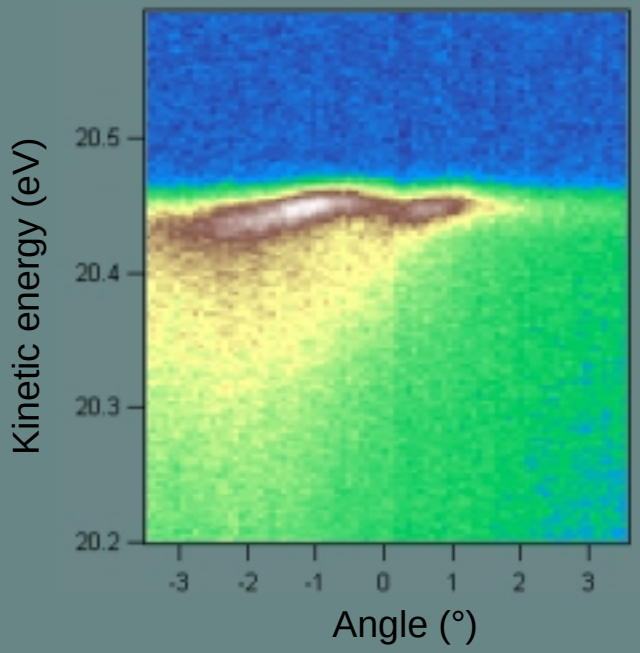
spin fluctuations

BCS-like superconducting gaps



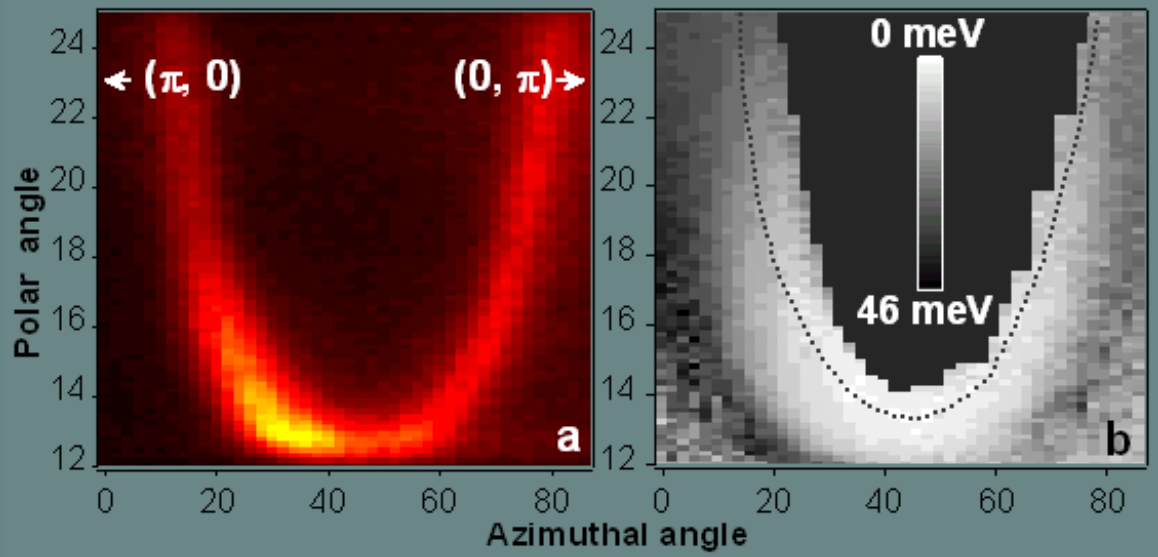


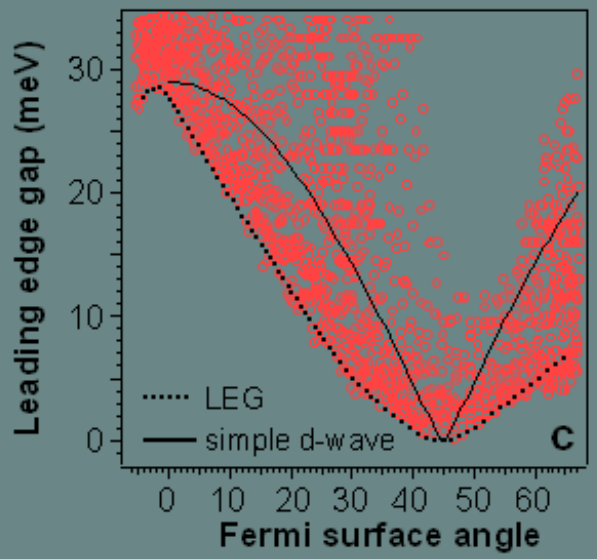




OD T=30K **UD**

Superconducting gap of the bonding sheet



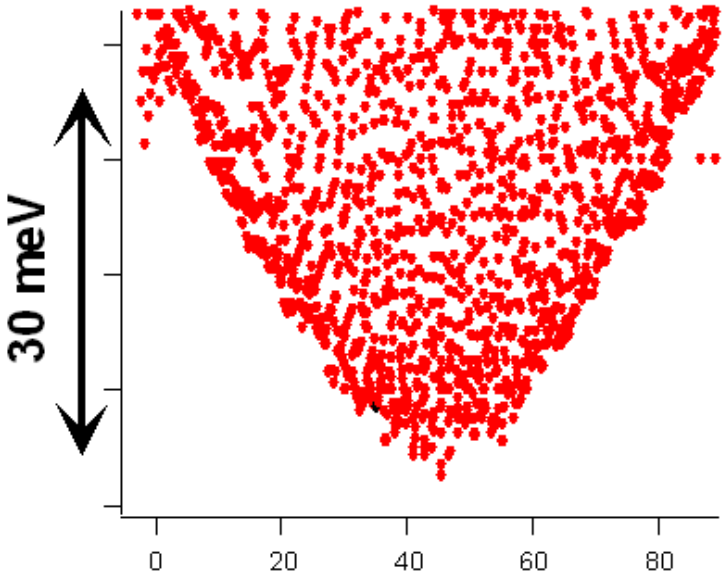


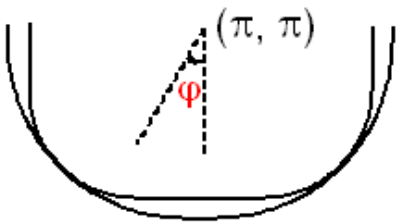
not a simple $\cos(k_x)$-$\cos(k_y)$ gap function

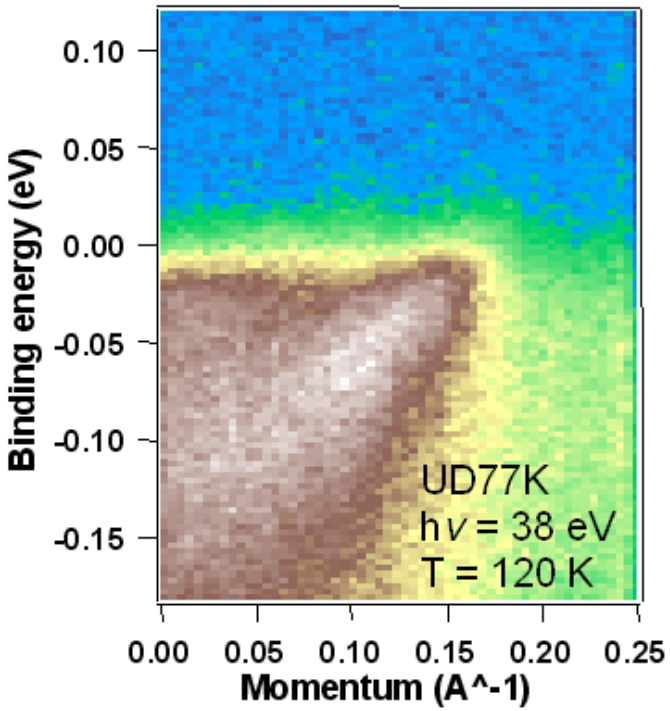
higher harmonics are important

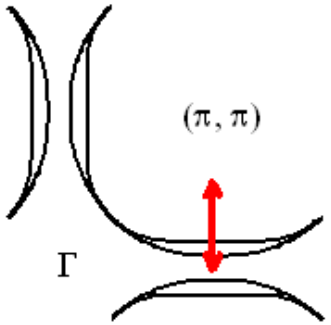
PRB(R)02

Pseudogap in the underdoped sample









cond-mat/04 (Borisenko et al., Eckl et al.)