ARPES on $Tl_2Ba_2CuO_{6+\delta}$: Probing the Electronic Structure of Overdoped Cuprates

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$Tl_2Ba_2CuO_{6+\delta}$: Collaborators

- **ARPES at UBC:**

  M. Platé, J. Mottershead, S. Hossain, S. Wang, P. Bloudoff, T. Pedersen, R. Norman, F. Cao, N. Ingle, **A. Damascelli**

- **Band Structure Calculations:**

  Ilya Elfimov

- **Samples:**

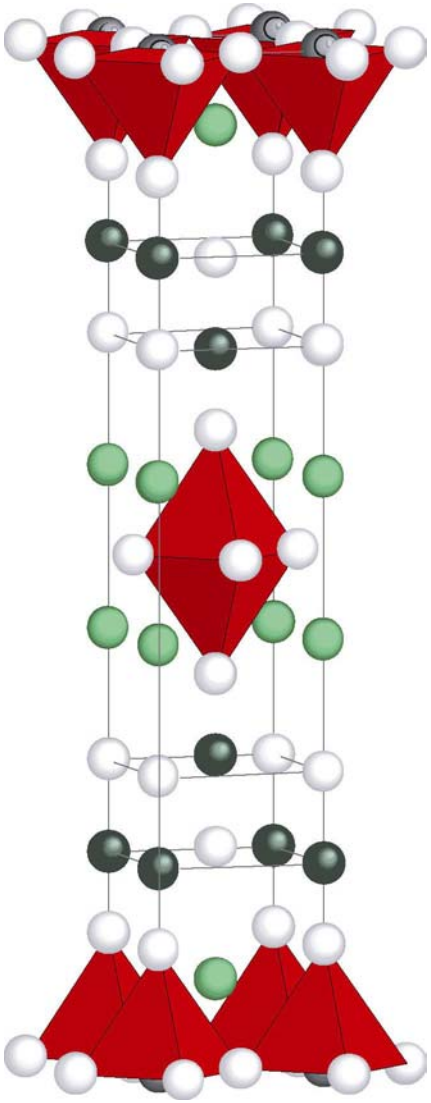
  $Tl_2Ba_2CuO_{6+\delta}$

  D. Peets, Ruixing Liang, D.A. Bonn, W.N. Hardy

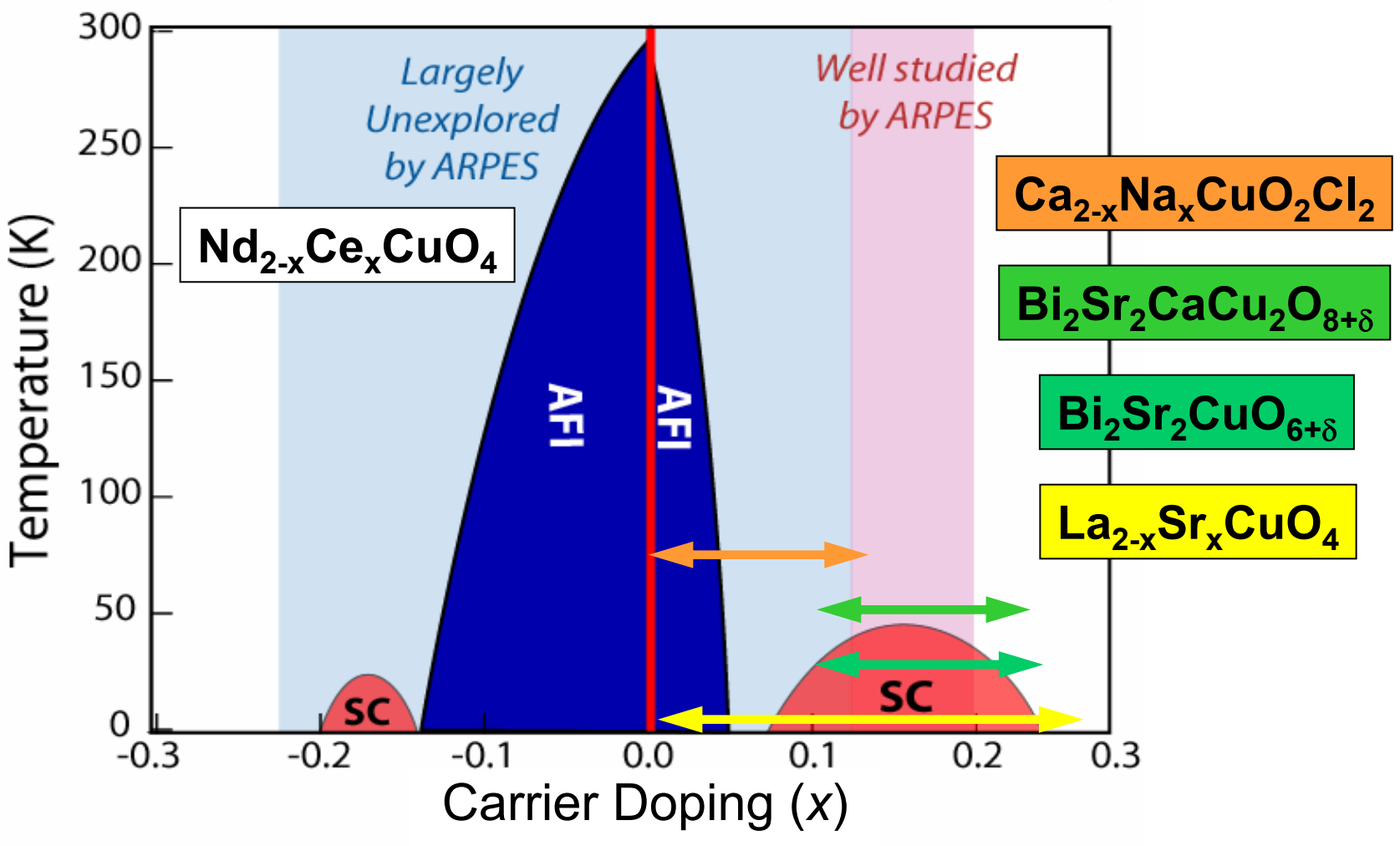
- **ARPES Experiments:**

  Swiss Light Source – SIS Beamline

  S. Chiuzbaian, M. Falub, M. Shi, L. Patthey



High-Temperature Superconductors

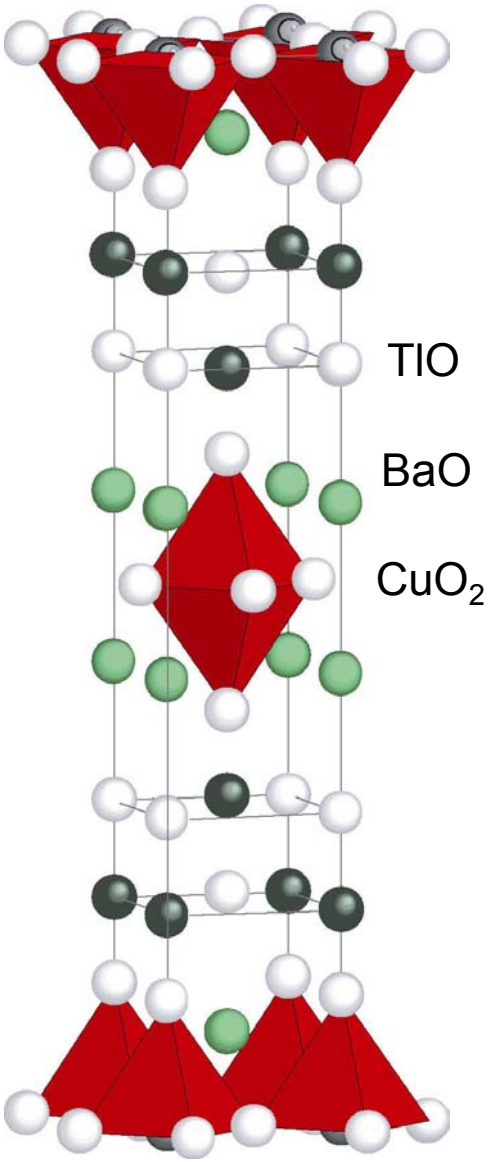


Why $Tl_2Ba_2CuO_{6+\delta}$?

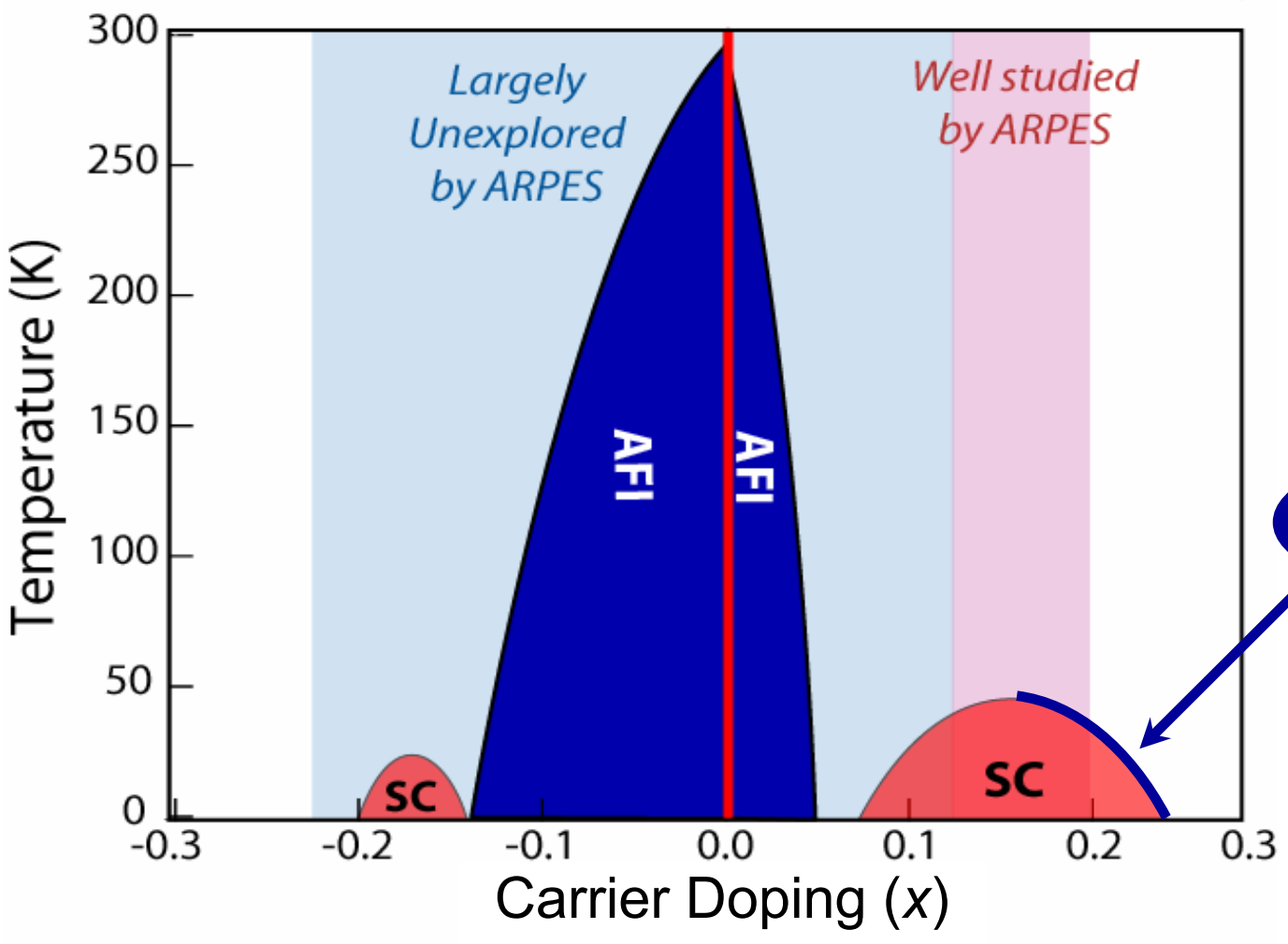
$Tl_2Ba_2CuO_{6+\delta}$: ideal HTSC material

- Single CuO_2 plane material
- Very high transition: T_c(opt)=93K
- No additional CuO chains
- No structural distortions
- Low cation disorder (T/O structure)

- $d_{x^2-y^2}$ SC gap (Tsuei et al., Nature 1997)
- (π,π) resonant mode (He et al., Science 2002)
- FS from AMRO (Hussey et al., Nature 2003)



ARPES on $Tl_2Ba_2CuO_{6+\delta}$



Tl2201

FL?

Paring mechanism?

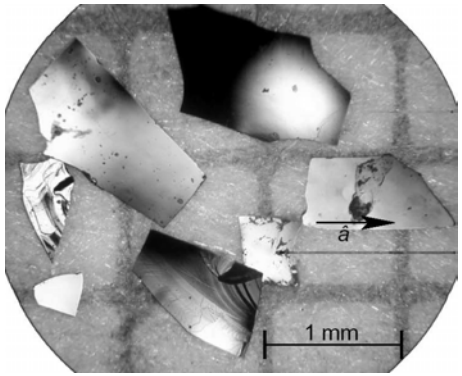
Quantum criticality?

Orthorhombic $Tl_2Ba_2CuO_{6+\delta}$

- **High-quality single crystals:**

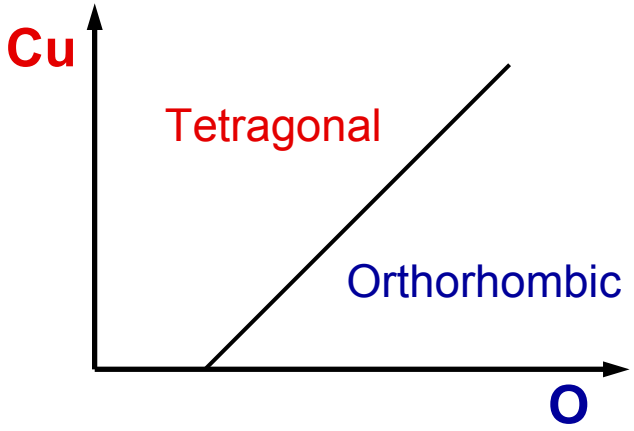
Orthorhombic Tl2201 grown by self-flux method

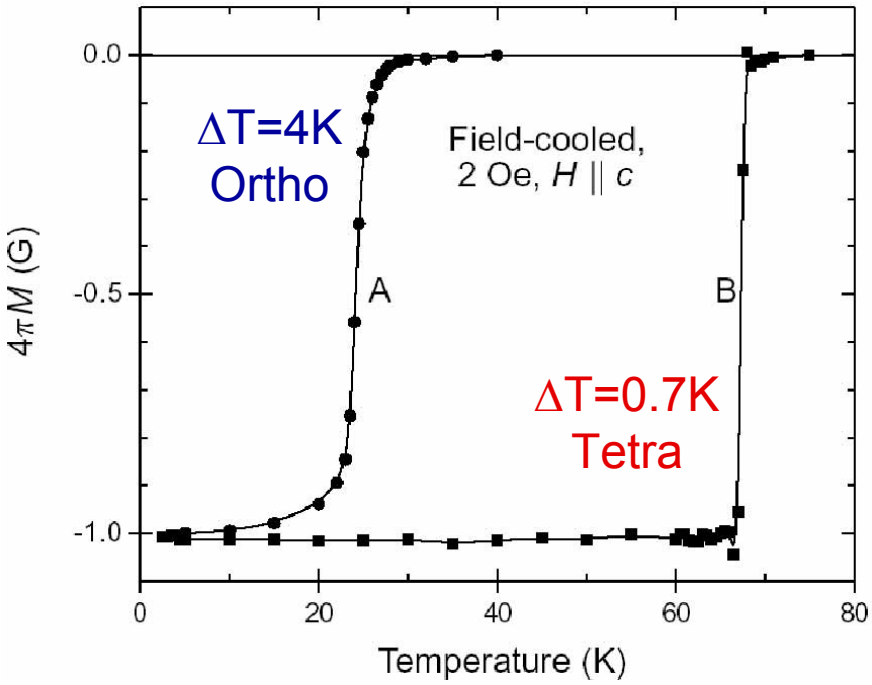
D. Peets, Ruixing Liang, D.A. Bonn, W.N. Hardy



Tetragonal (a=3.865Å; c=23.247Å)

Orthorhombic (a=5.458Å; b=5.485; c=23.201Å)





Ortho as-grown $Tl_{1.88}Ba_2Cu_{1.11}O_{6+\delta}$

Peets et al., cond-mat/0211028

Swiss Light Source – SIS Beamline

- **ARPES Experiments:**

  Surface and Interface Spectroscopy Beamline

  S. Chiuzbaian, M. Falub, M. Shi, **L. Patthey**

- **Twin Undulator**
- **Monochromator**

  Energy Range: 10-800 eV

  Polarization: circular/planar

- **ARPES**

  Detector: SES2002

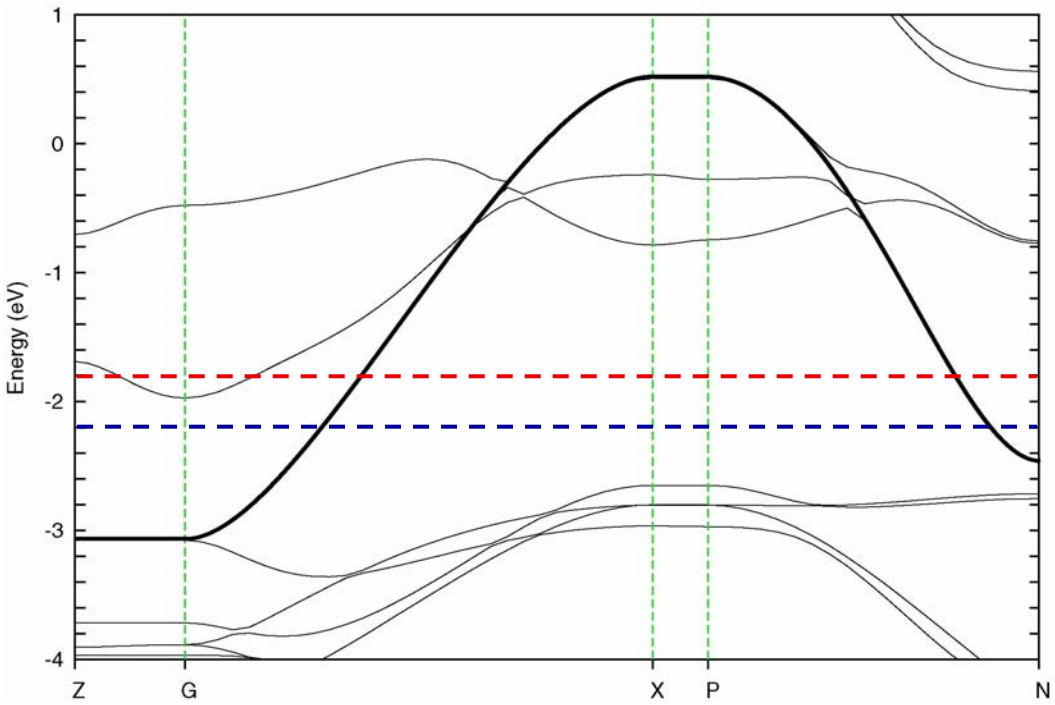
  $E/\Delta E > 10^4$; $\Delta k = 0.3^o$

  Low T: 10-300K

  spot size: 20x20 μm^2

- **Spin resolved ARPES**

Tl2201: Low energy electronic structure

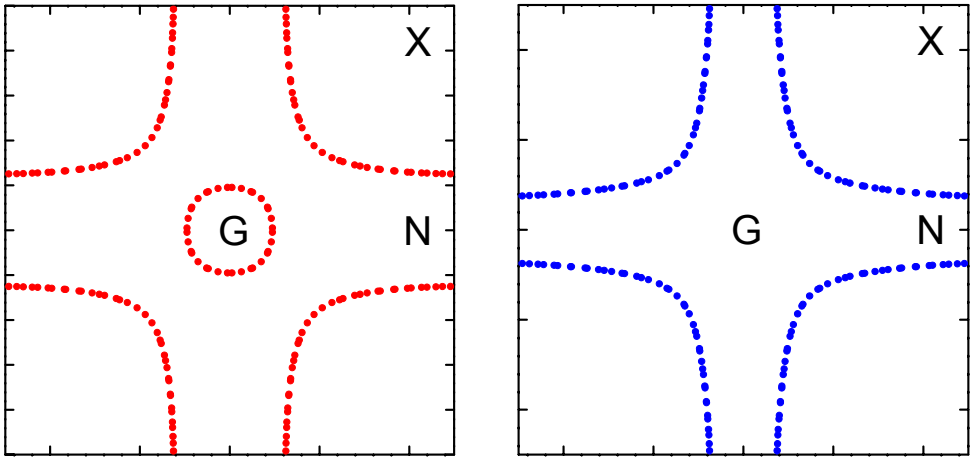


Tl^{3+}:Ba^{2+}:Cu^{2+}:O^{2-} in ratios 2:2:1:6

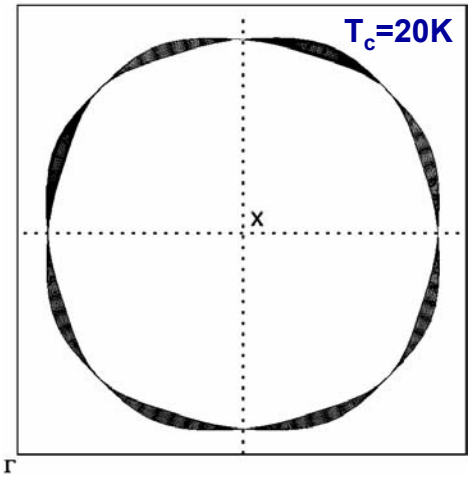
Charge Transfer Insulator

- Short Tl-O distance
  - ➡ CuO band not ½ filled
- Cu-Tl substitution
  - ➡ Additional hole-doping

Tl2201: Optimally Doped SC

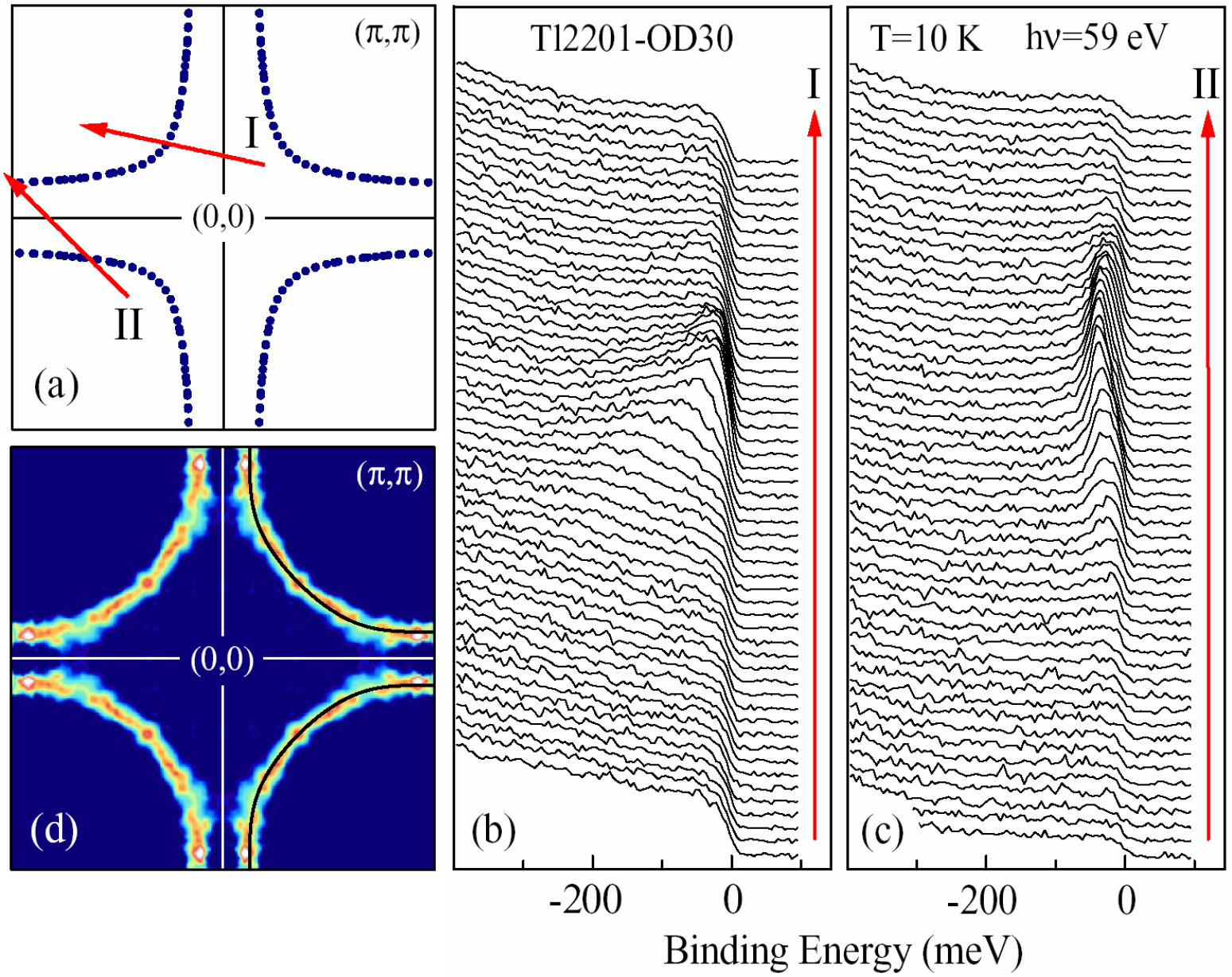


Elfimov (2004)



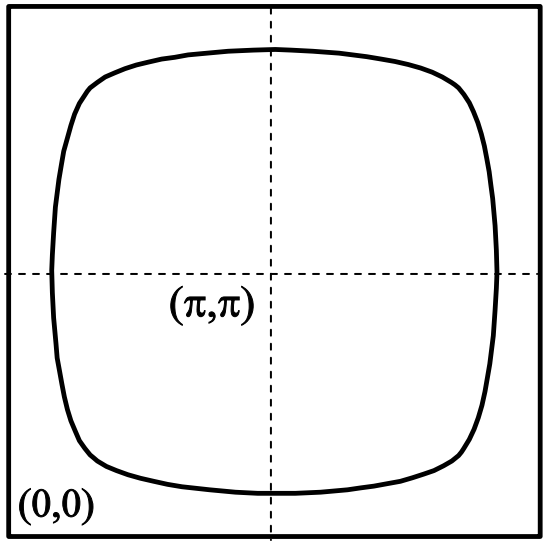
Hussey et al, Nature **425**, 814 (2004)

Tl2201 : ARPES Results

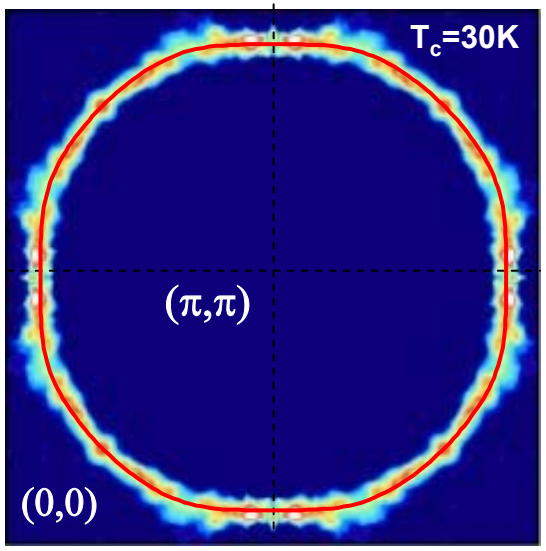


Tl2201 : Fermi Surface Volume

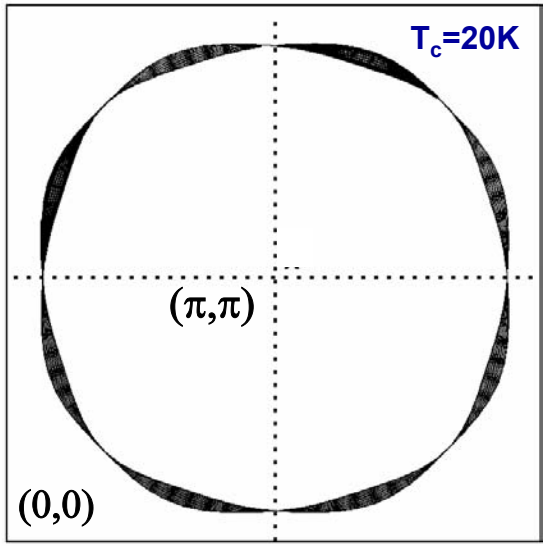
LDA



ARPES



AMRO



Hussey et al, Nature **425**, 814 (2004)

Hole FS volume

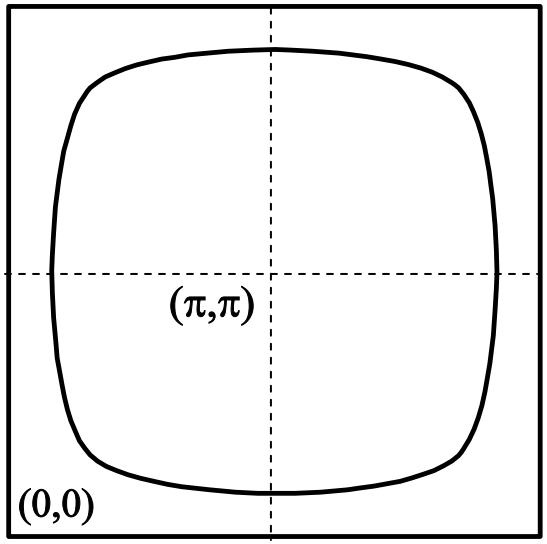
63%
p=0.26/Cu

63%
p=0.26/Cu

62%
p=0.24/Cu

Tl2201 : Fermi Surface Volume

LDA



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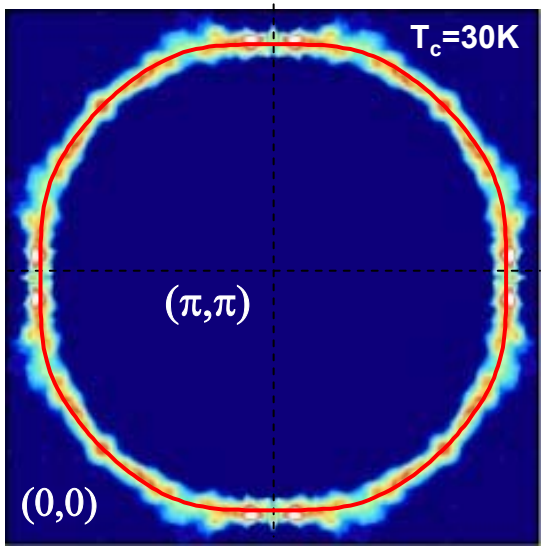
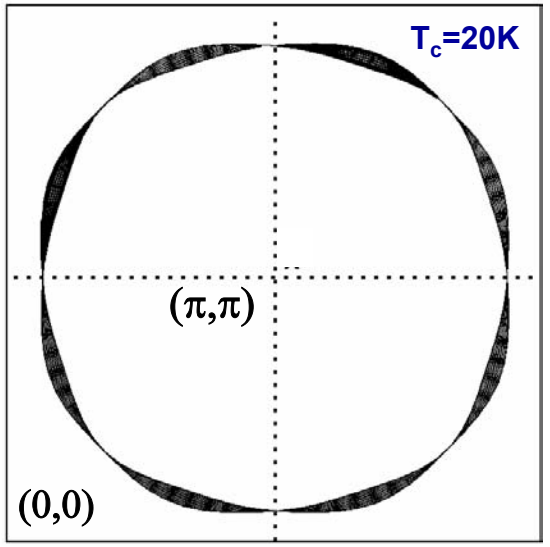


AMRO

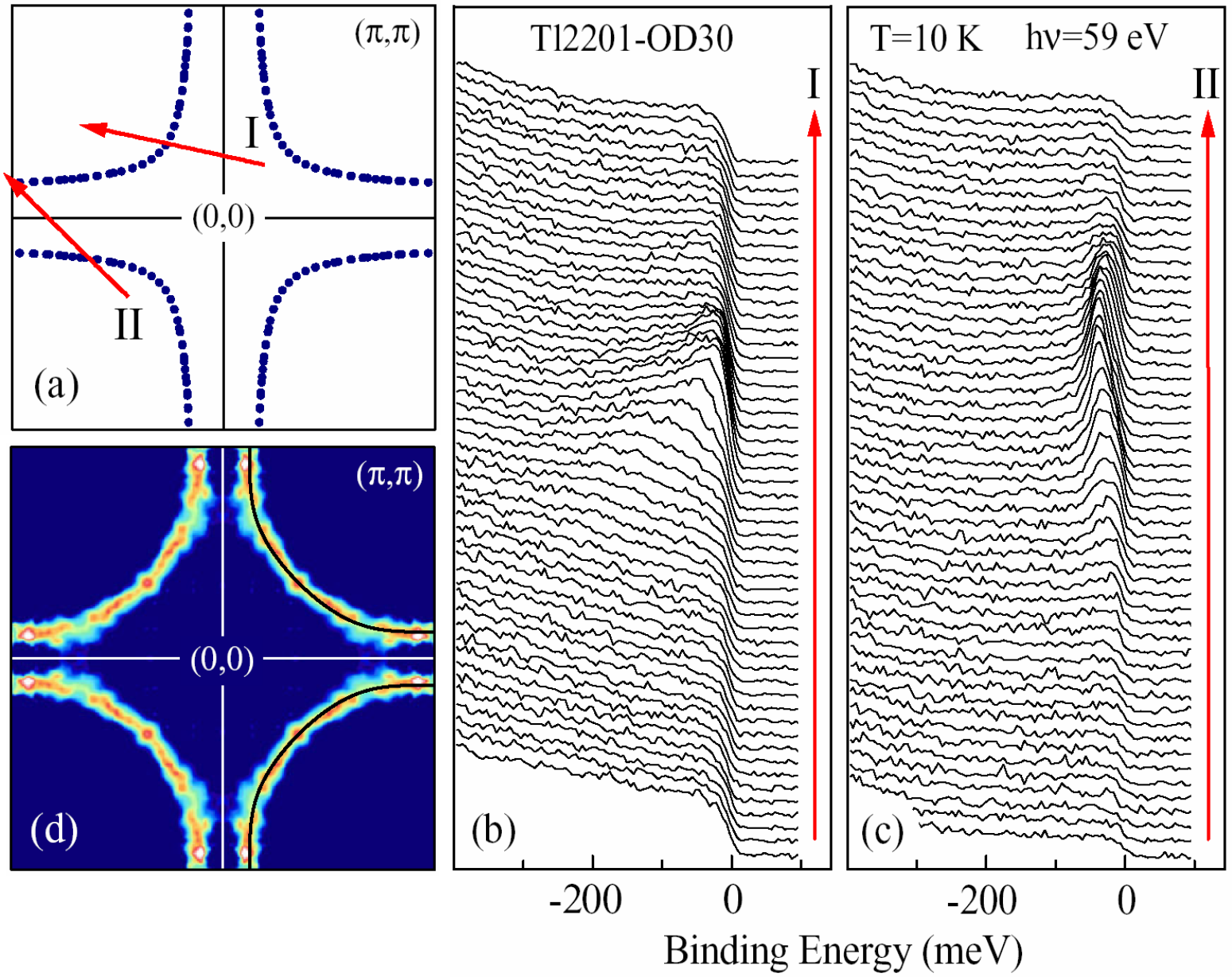


Hussey et al, Nature **425**, 814 (2004)

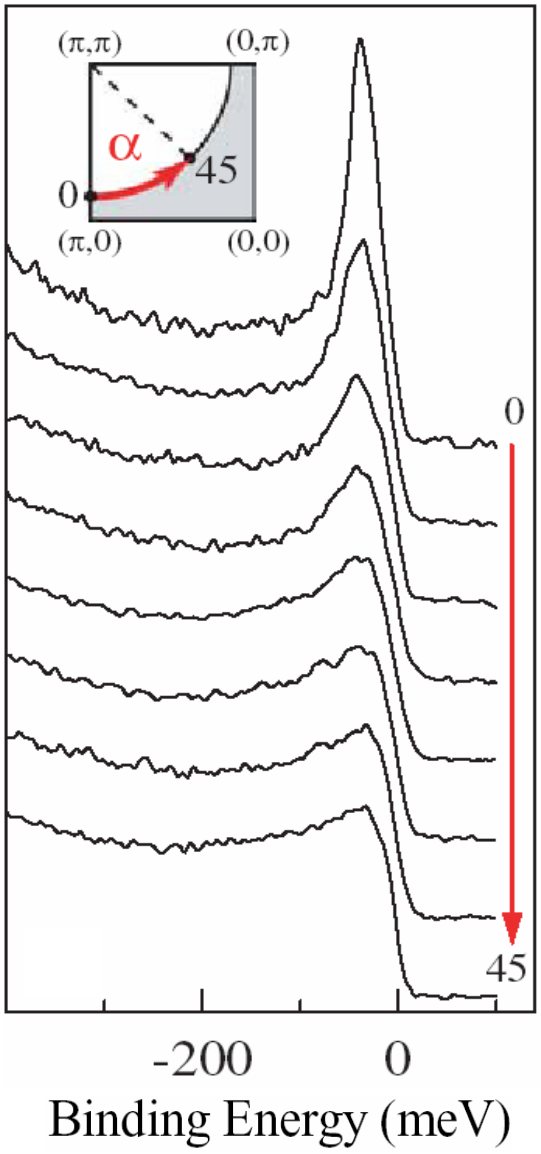
Tight binding FS fit

$$\epsilon_{\mathbf{k}} = \mu + \frac{t_1}{2}(\cos k_x + \cos k_y) + t_2 \cos k_x \cos k_y + \frac{t_3}{2}(\cos 2k_x + \cos 2k_y)$$
$$+ \frac{t_4}{2}(\cos 2k_x \cos k_y + \cos k_x \cos 2k_y) + t_5 \cos 2k_x \cos 2k_y$$

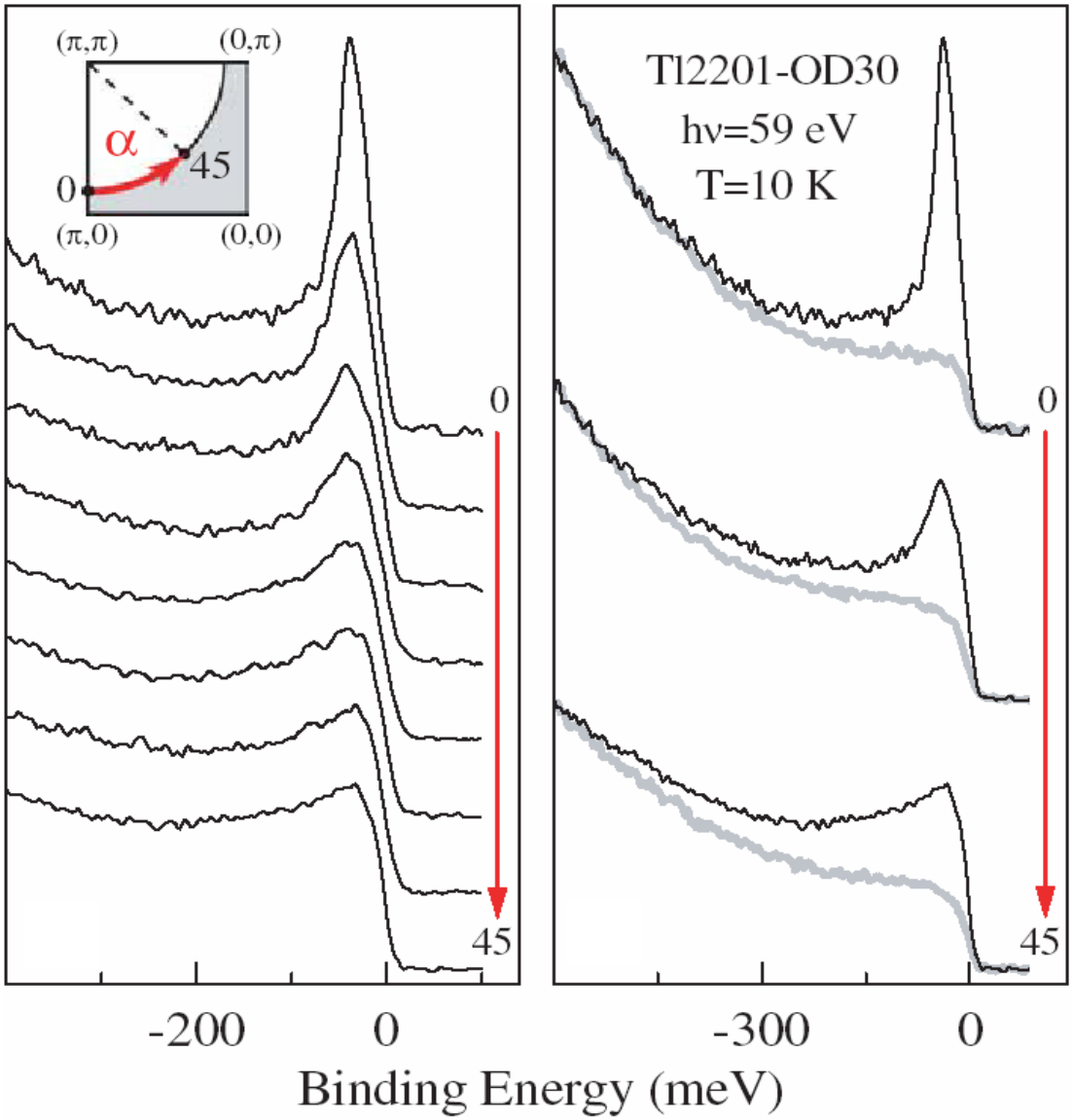
Tl2201: ARPES Results



TI2201: Lineshape evolution



Tl2201: Lineshape evolution



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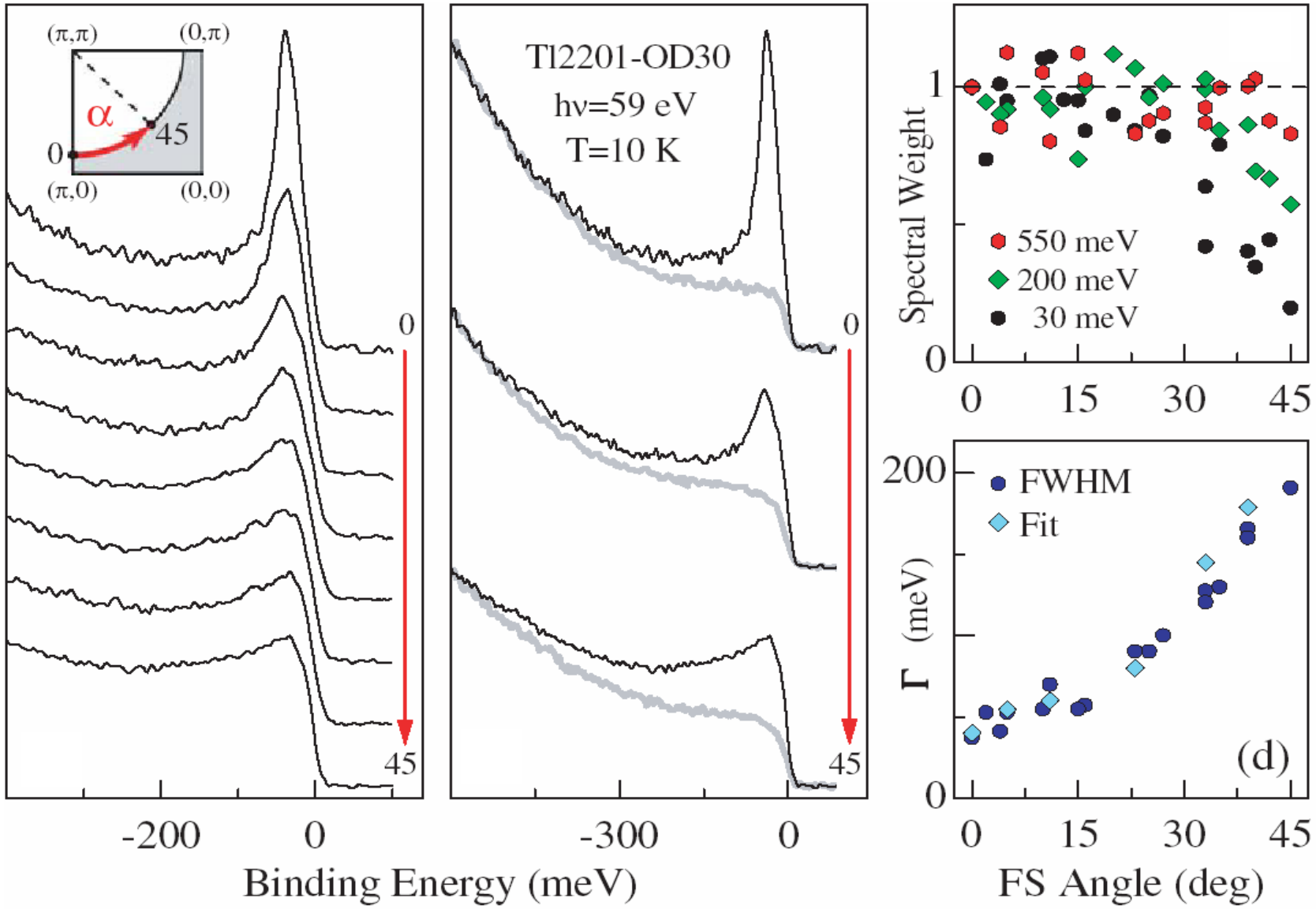
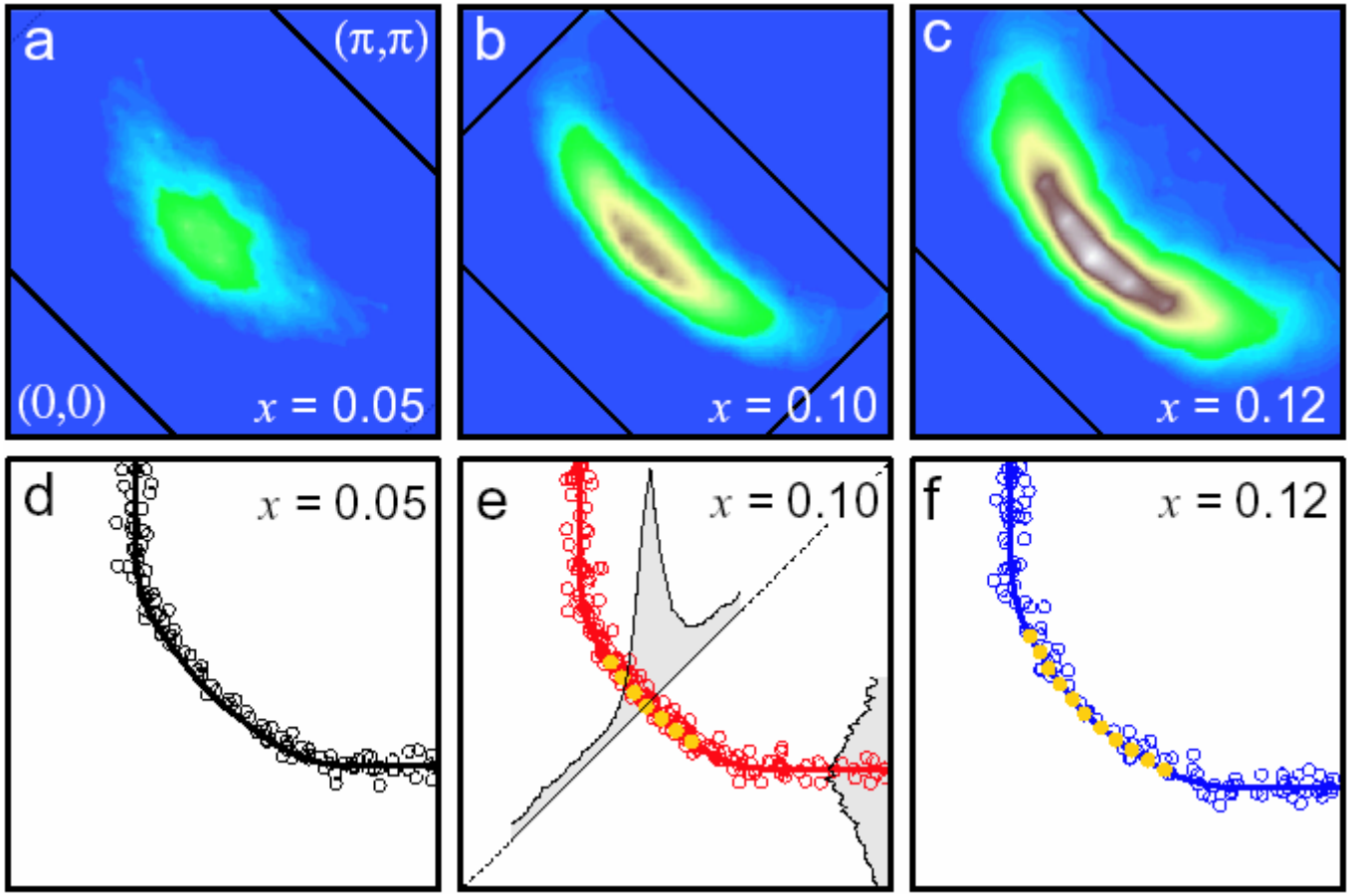


FS and Pseudogap in Underdoped Cuprates

ARPES on $Ca_{2-x}Na_xCuO_2Cl_2$



K.M. Shen *et al.*, Science **307**, 901 (2005)

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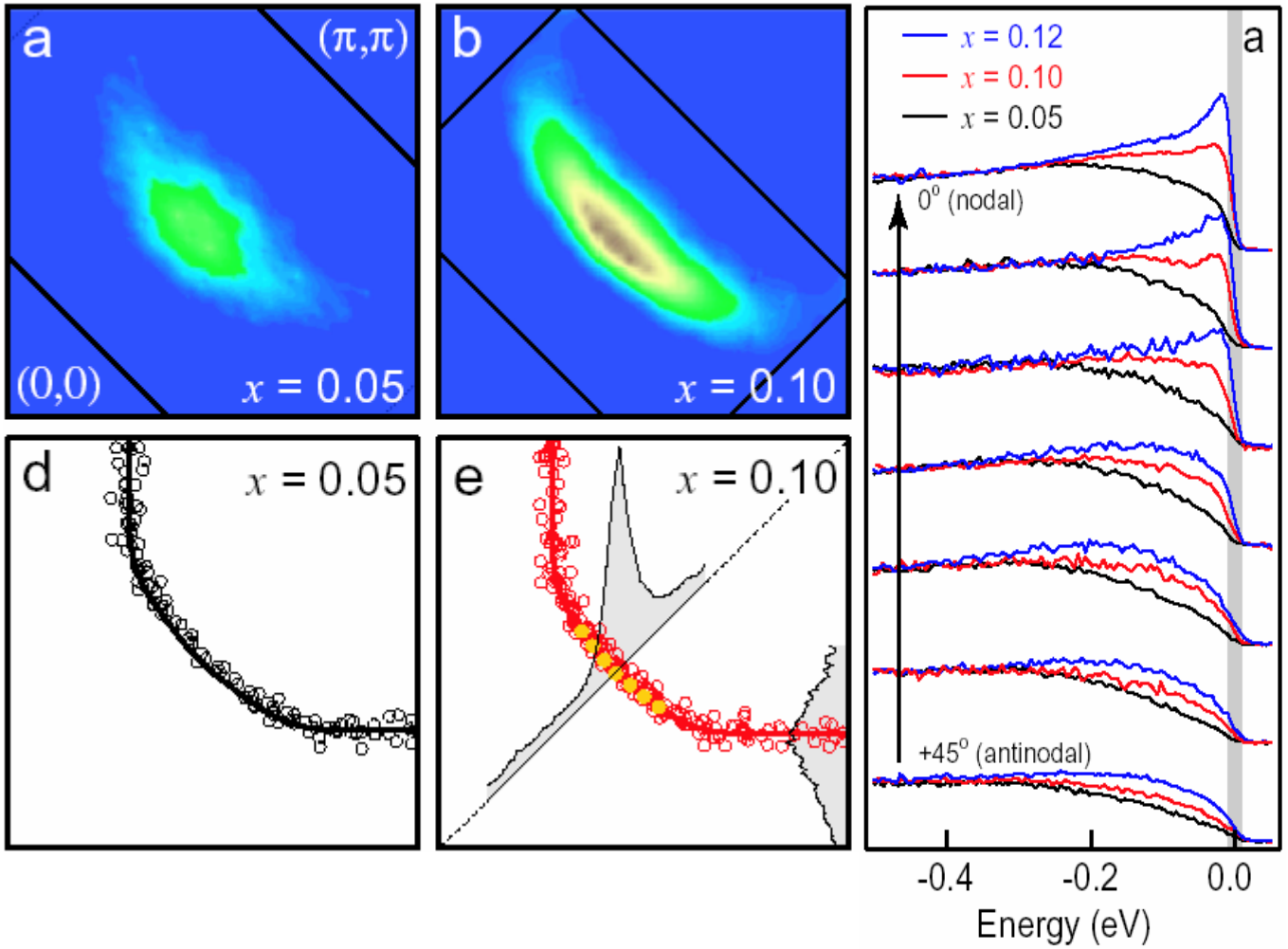

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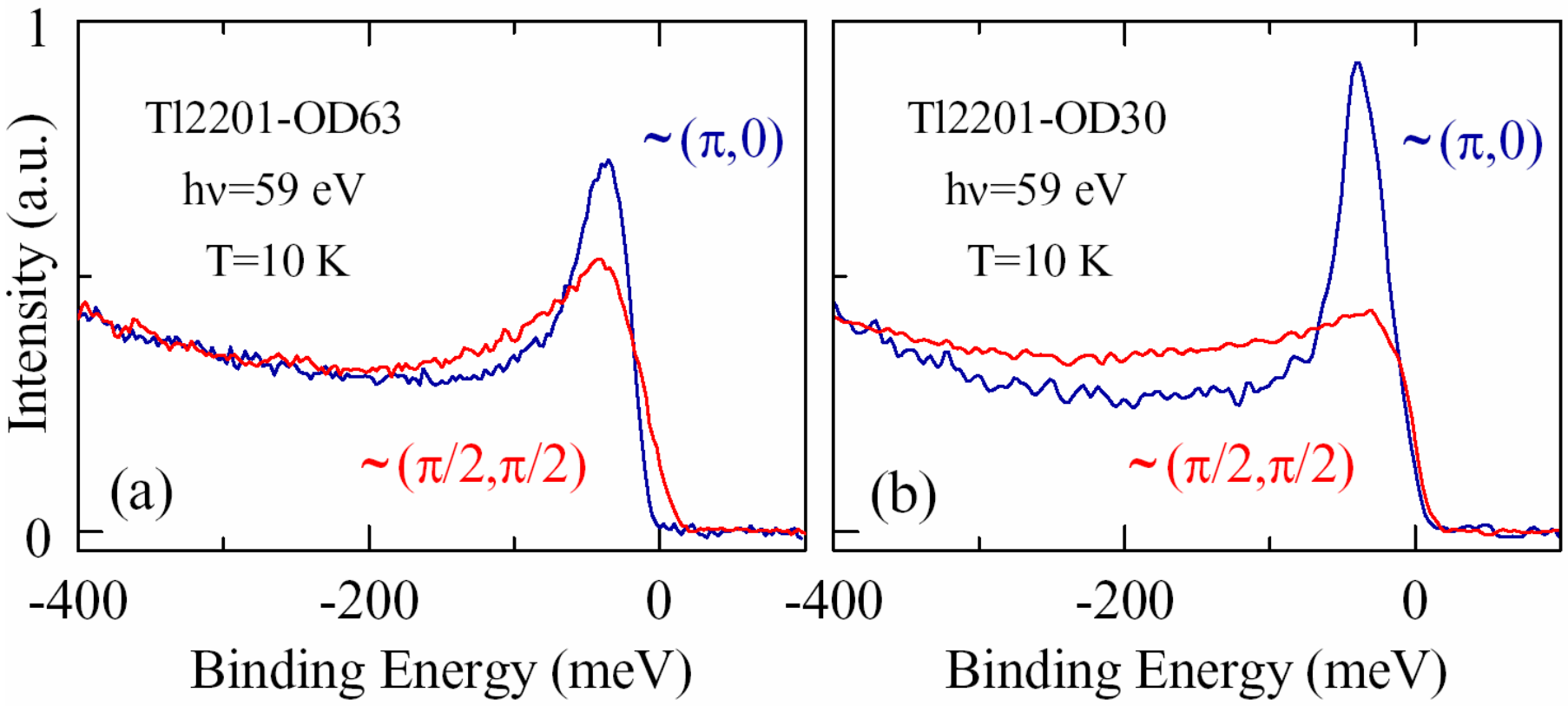
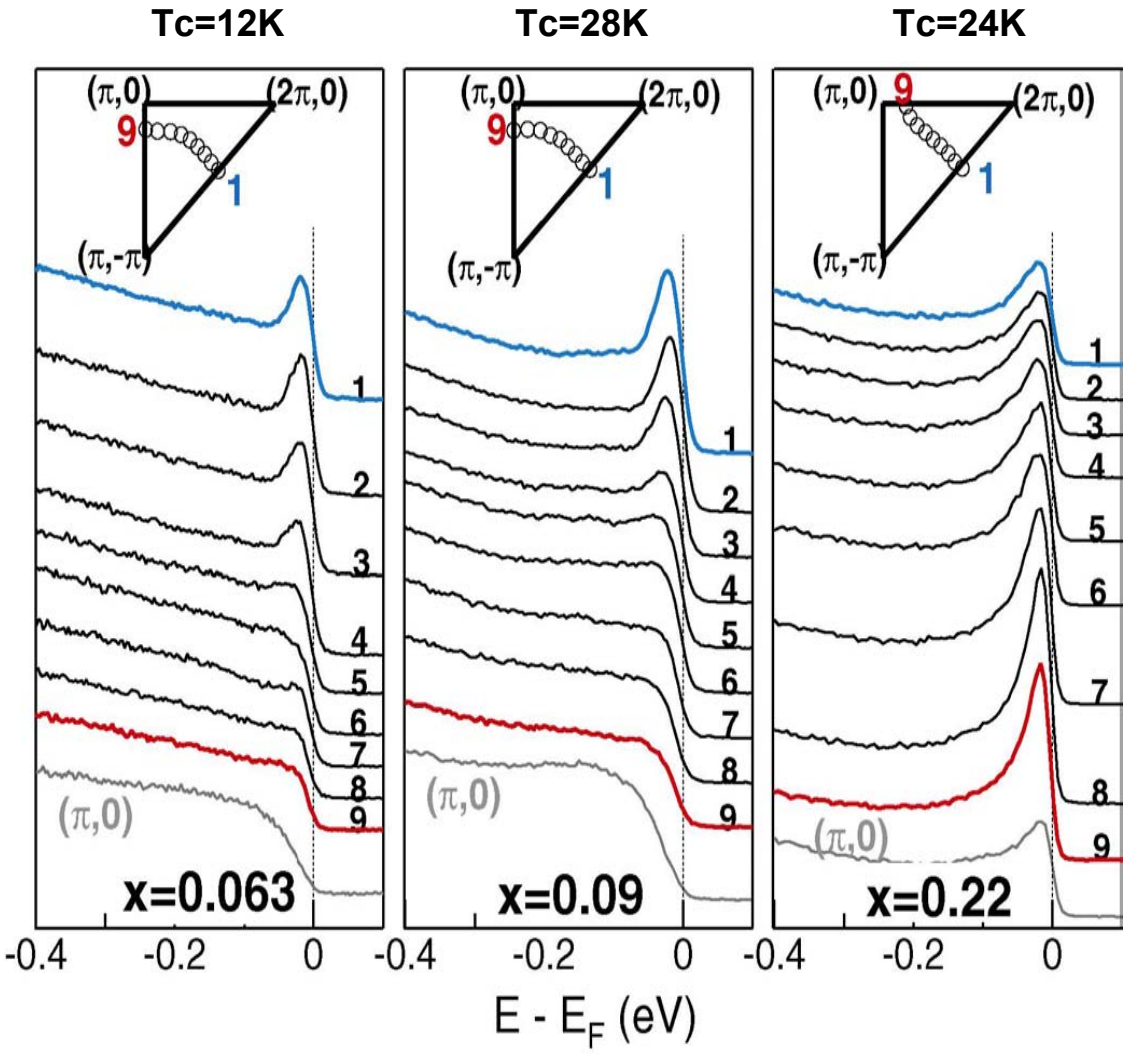
$Tl_2Ba_2CuO_{6+\delta}$: ARPES Results



$Tl_2Ba_2CuO_{6+\delta}$: Lineshape evolution

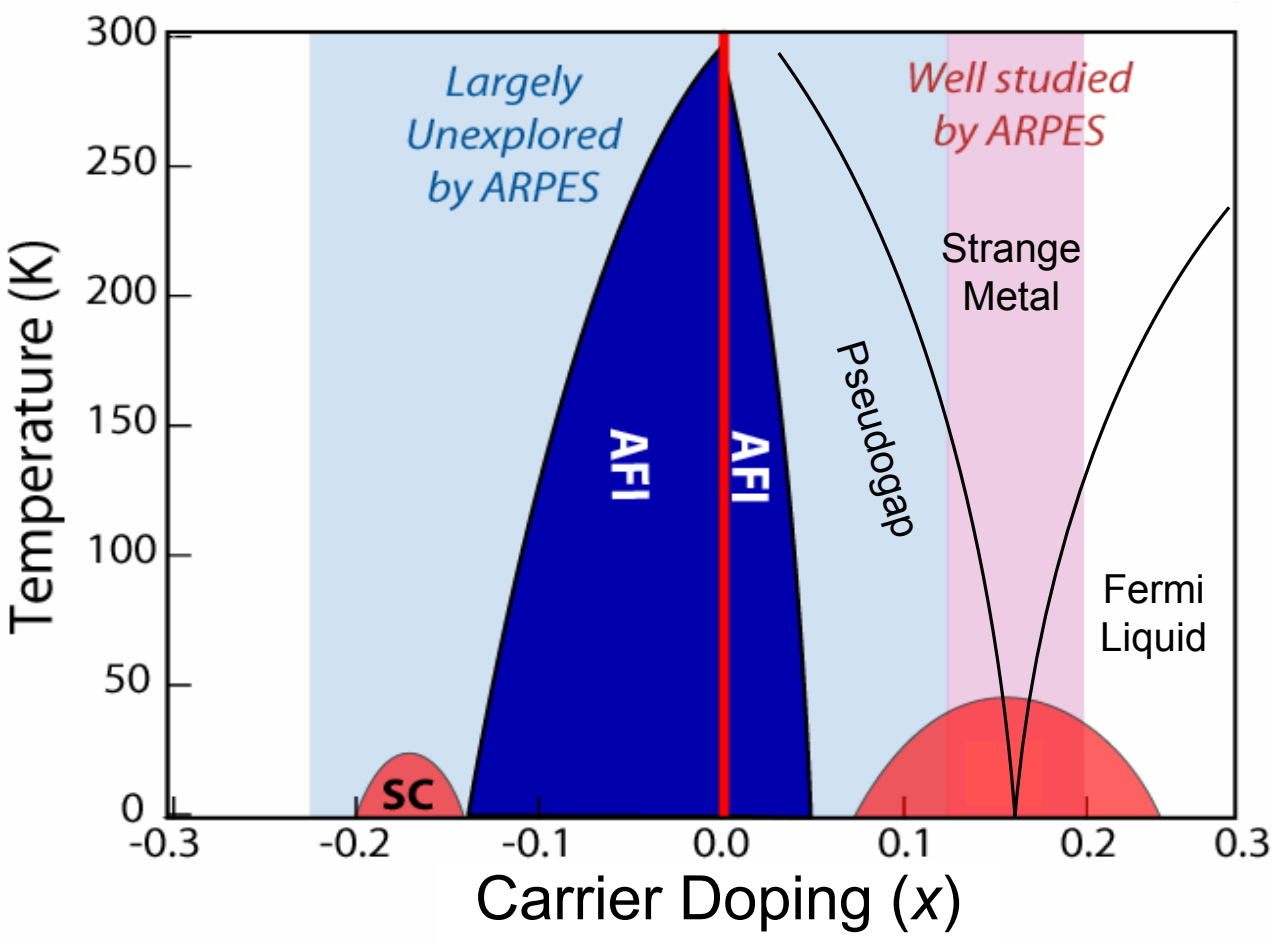
LSCO



X.J. Zhou et al., PRL **92**, 187001 (2004)

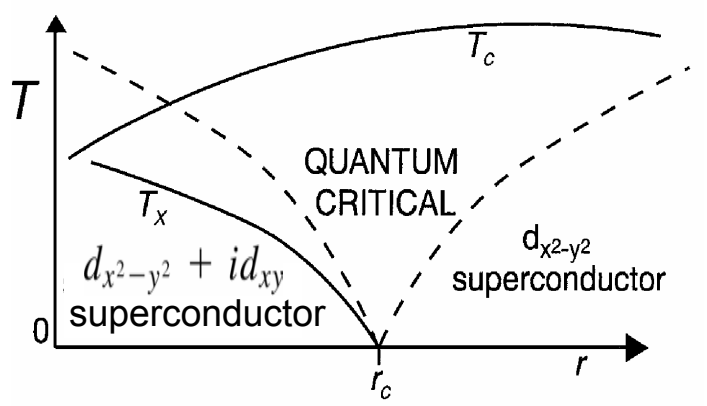
Tl2201: Quantum Critical Point?

QP anisotropy reversal



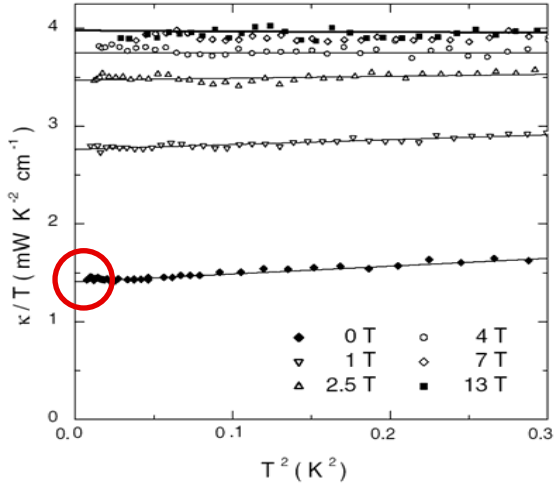
Quantum criticality?

TI2201: SC gap symmetry

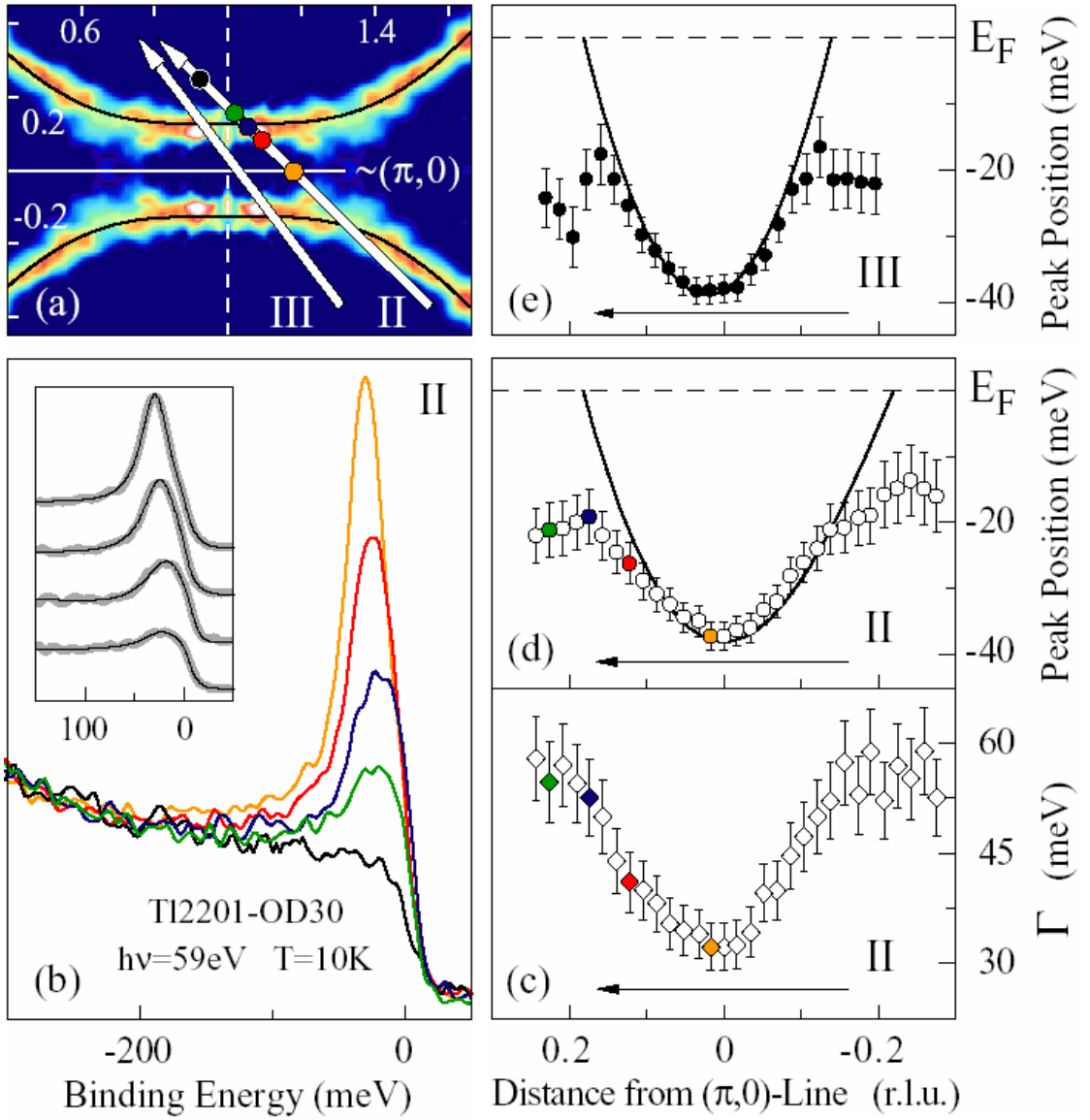


Vojta, Zhang, Sachdev, PRL 2000

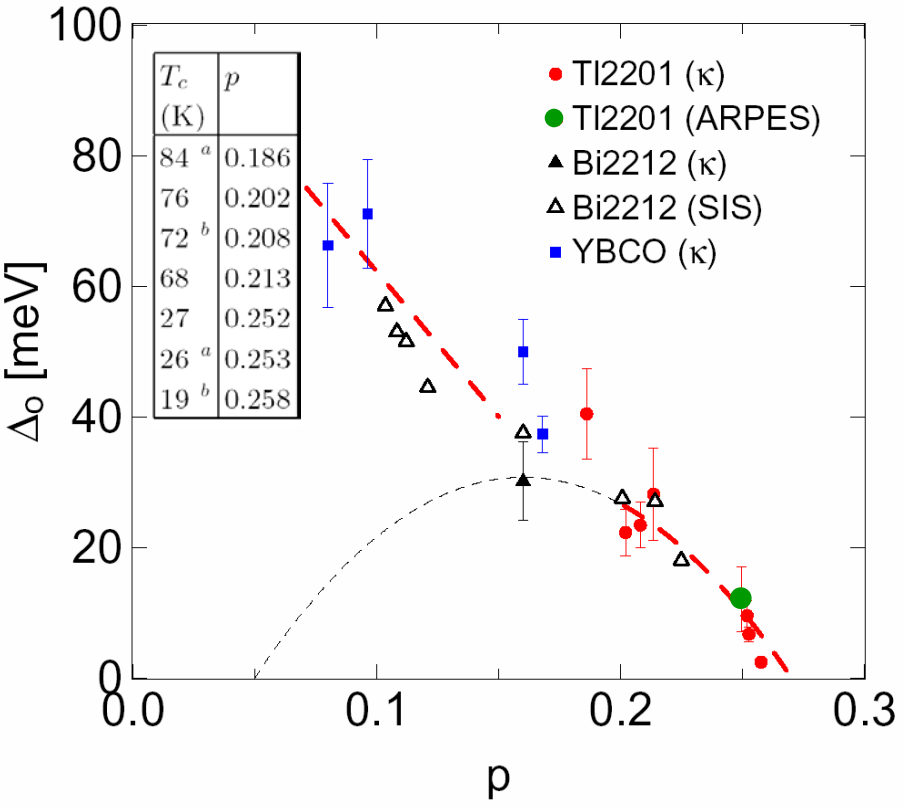
Large residual linear term in heat conductivity



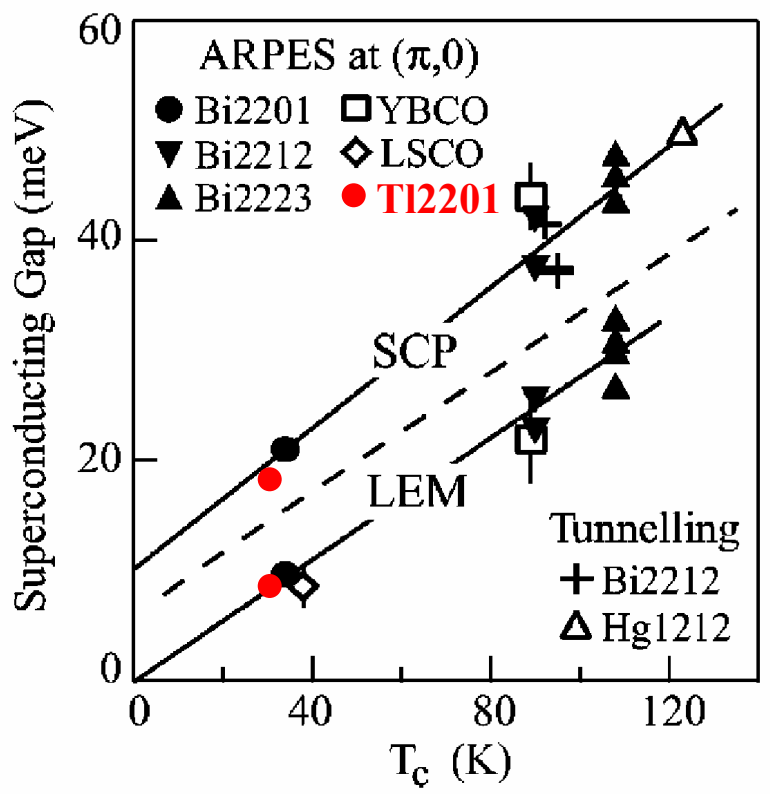
Proust et al., PRL 2002



Tl2201: SC gap symmetry



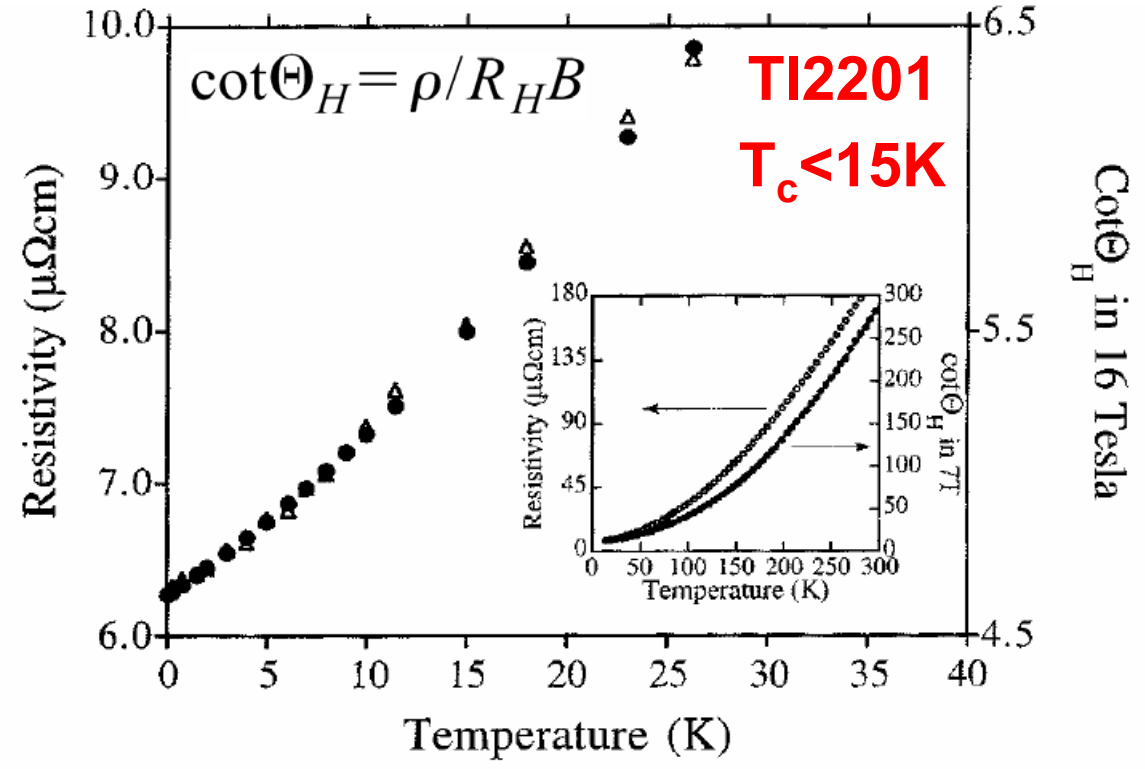
D.G. Hawthorn *et al.*,
cond-mat/0502273 (2005)



D.L. Feng, A. Damascelli *et al.*,
PRL **88**, 107001(2002)

TI2201: Momentum Dependent Scattering?

Electronic scattering appears
isotropic in overdoped cuprates

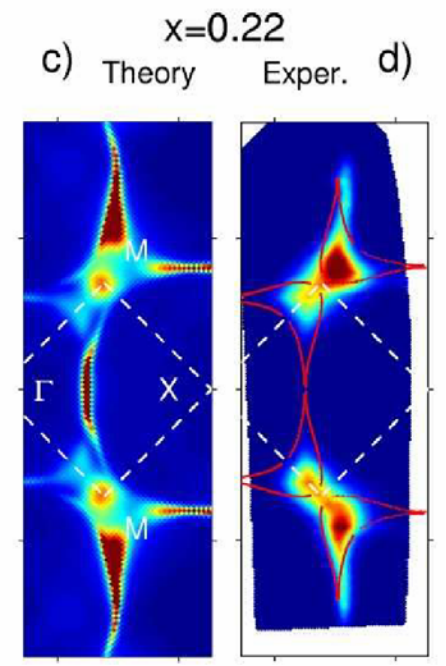


A. Mackenzie *et al.*, PRB **53**, 5848 (1996)

Residual k_z-dispersion

Forward scattering

Tl2201 : Residual k_z Dispersion?



Sahrakorpi et al,
cond-mat/0501500 (2005)

ARPES

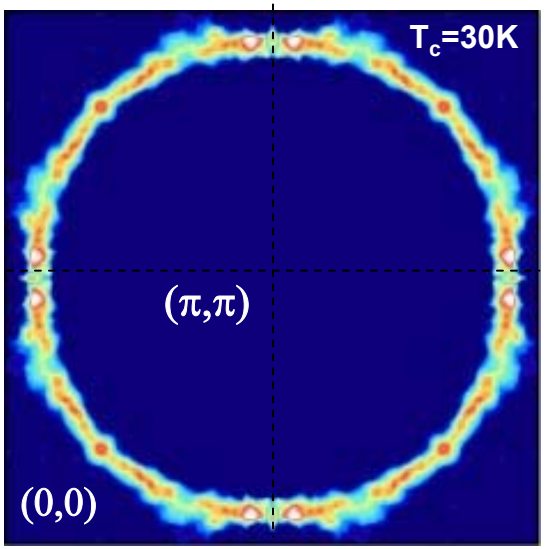
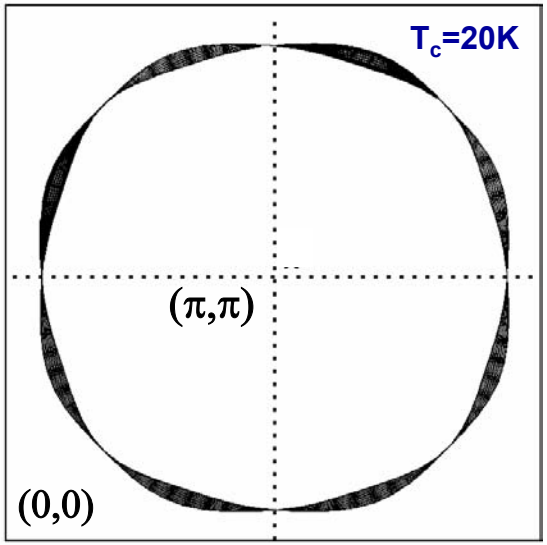


Plate et al,
cond-mat/0503117 (2005)

AMRO



Hussey et al,
Nature **425**, 814 (2004)

TI2201: Small Angle Scattering?

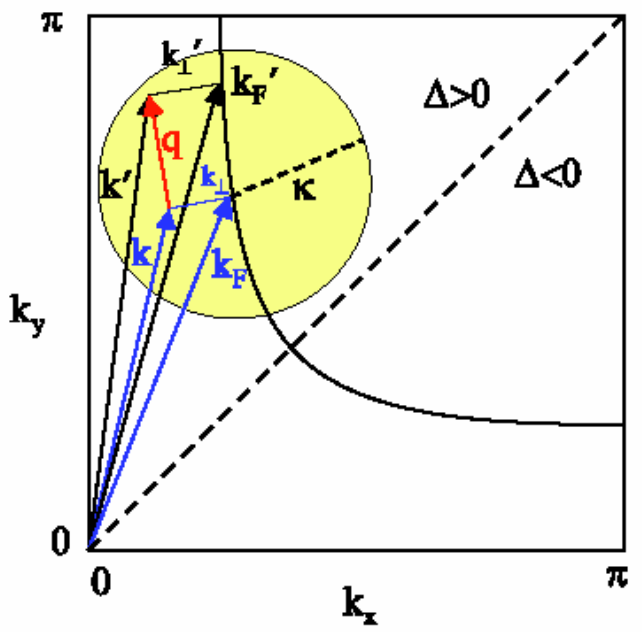
$$\underline{\Sigma}_{tot} = \underline{\Sigma}_{el,f} + \underline{\Sigma}_{\mathrm{el,u}} + \underline{\Sigma}_{\mathrm{inel}}$$

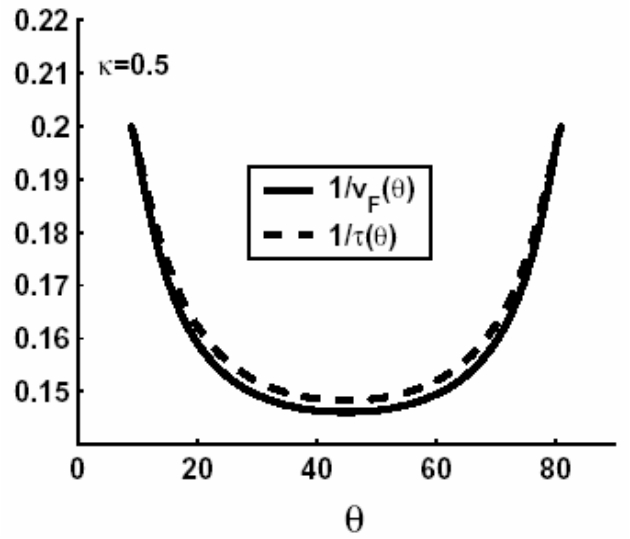
$$V(r) = V_0 e^{-\kappa r}$$

$$V_{\mathbf{k}\mathbf{k}'} = \frac{2\pi\kappa V_0}{((\mathbf{k}-\mathbf{k}')^2 + \kappa^2)^{3/2}}$$

$$\Sigma(\mathbf{k},\omega) = n_I \sum_{k'} |V_{\mathbf{k}\mathbf{k}'}|^2 G^0(\mathbf{k}',\omega)$$

$$-\Sigma''(\mathbf{k}_F,0) \equiv \Gamma_0(\mathbf{k}_F) = \frac{3\pi n_i V_0^2}{8|v_F(\mathbf{k}_F)|\kappa^3}$$

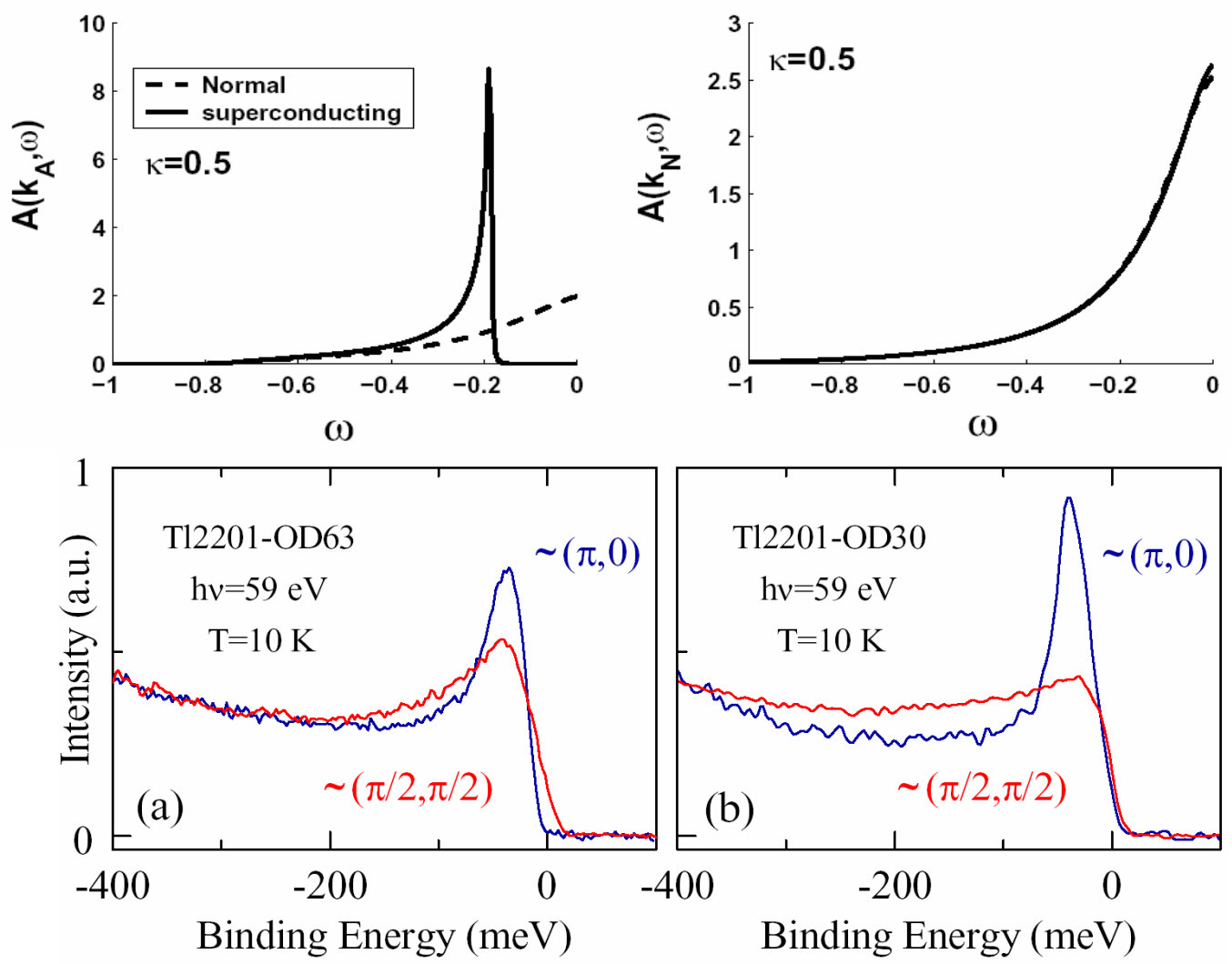




Zhu, P.J. Hirschfeld, & D.J. Scalapino, PRB **70**, 214503 (2004)

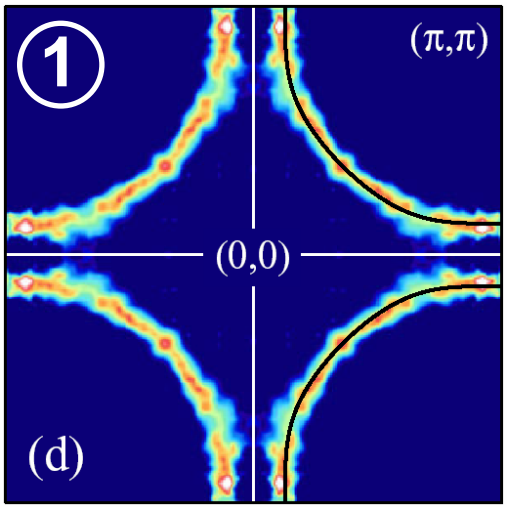
Tl2201: Small Angle Scattering?

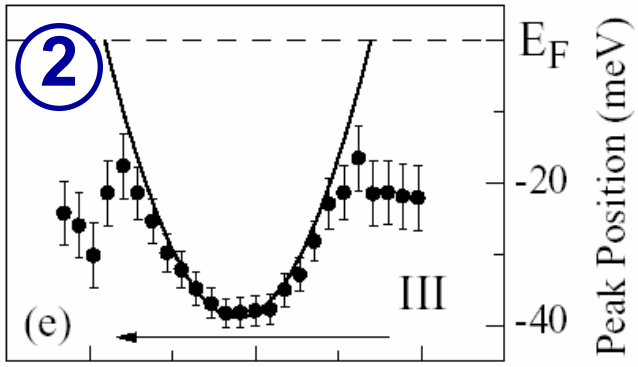
Small Angle Scattering: strong T-dependence at (π,0)

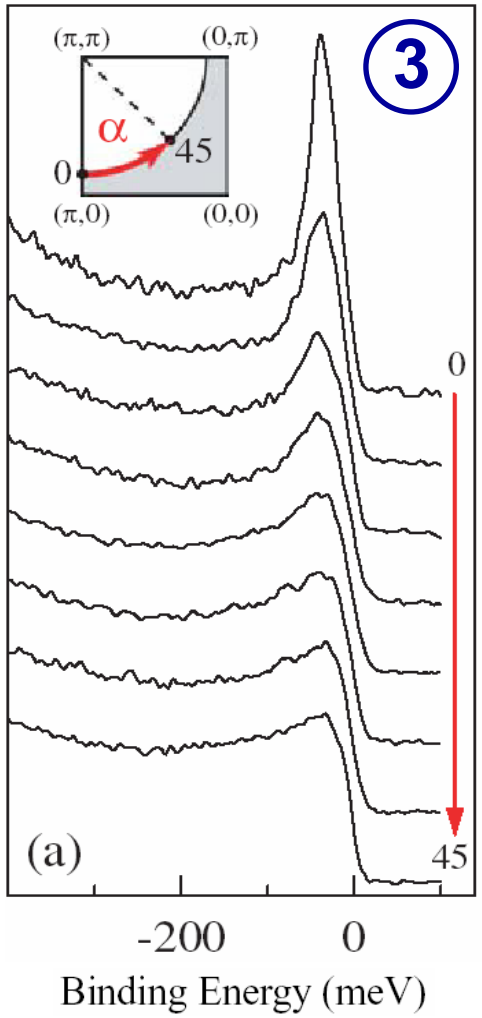


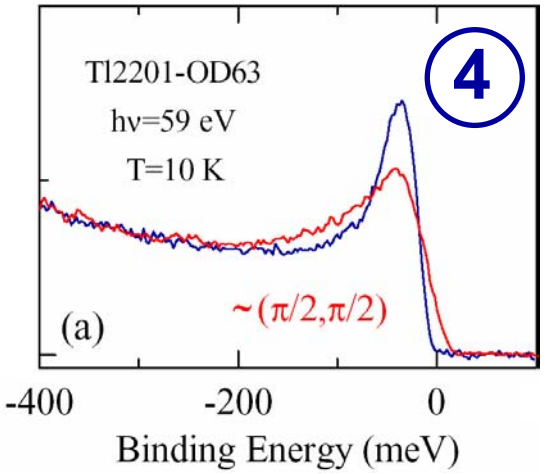
Zhu, P.J. Hirschfeld, & D.J. Scalapino, PRB **70**, 214503 (2004)

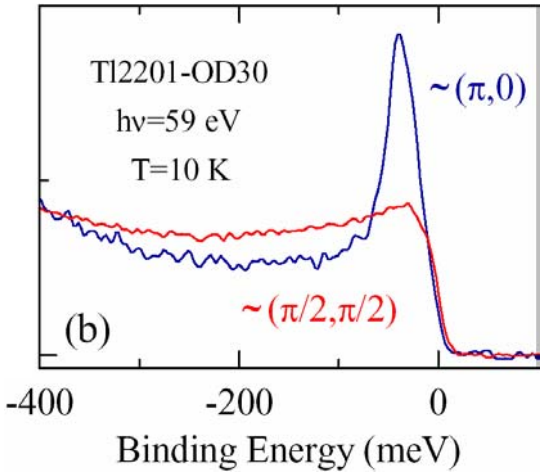
ARPES on Tl2201: Conclusions











M. Platé, J. Mottershead, A. Damascelli, et al., cond-mat/0503117