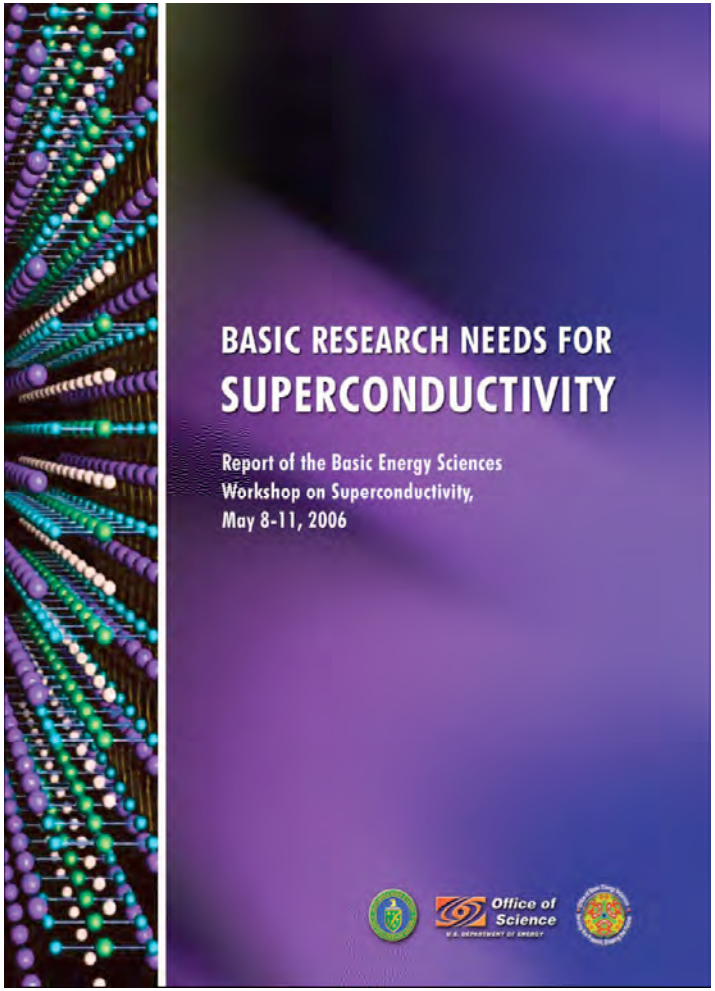
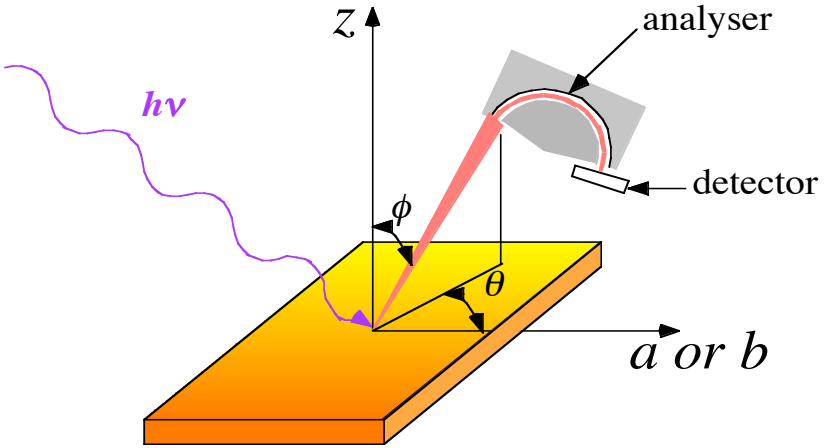
Important aspects related to the pairing mechanism of iron-based superconductors revealed by ARPES

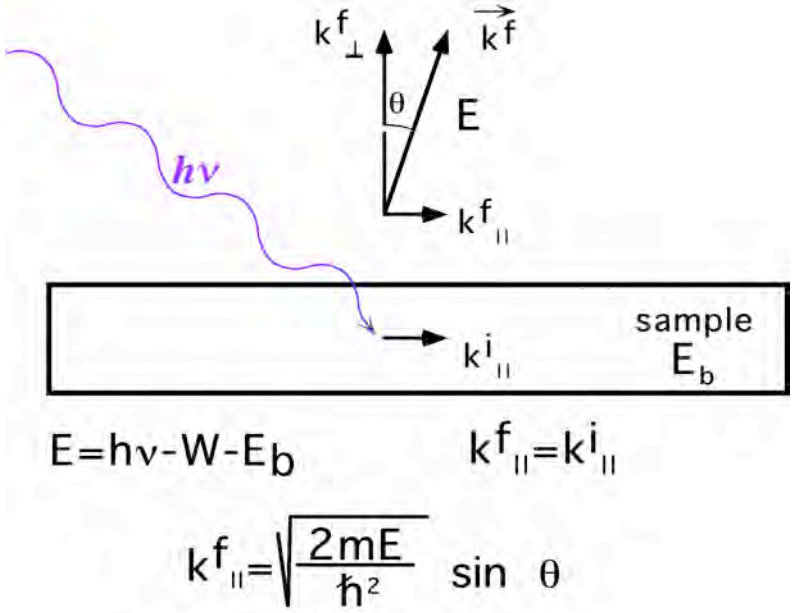
丁洪
中科

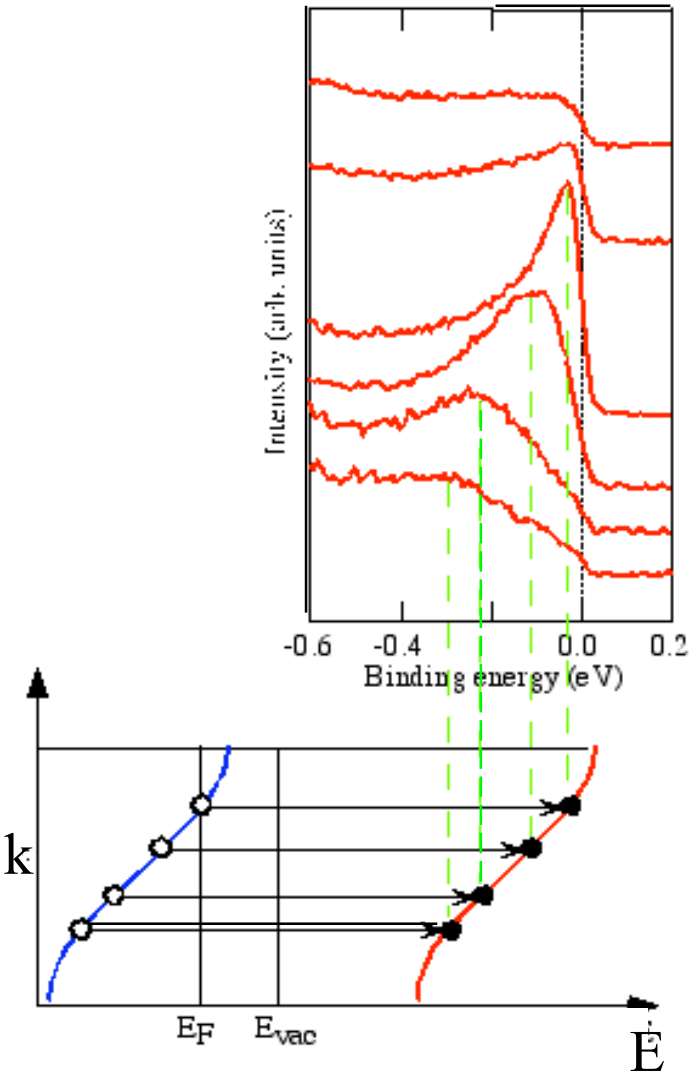
Emerging Experimental Techniques and Opportunities



- *Angle-Resolved Photoemission Spectroscopy* (*ARPES*). Wavelike quantum states of the electrons are defined in momentum space (*k*-space). ARPES allows direct

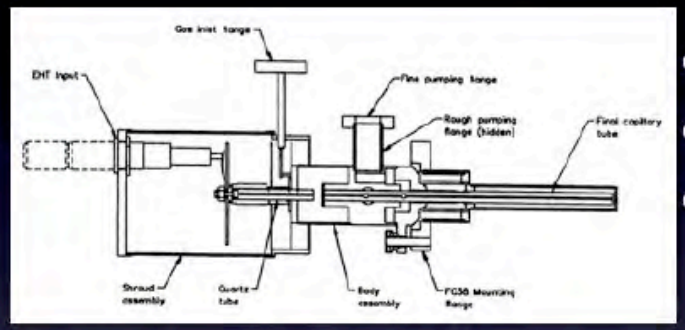

z
analyser
hν
detector
ϕ
θ
a or b


k f ⊥
k f
θ
E
hν
k f ||
sample
E b
k i ||
E=hν-W-E b
k f ||=k i ||
k f ||=√(2mE/ħ²) sin θ


Intensity (arb. units)
-0.6
-0.4
0.0
0.2
Binding energy (eV)
k
E F
E vac
E

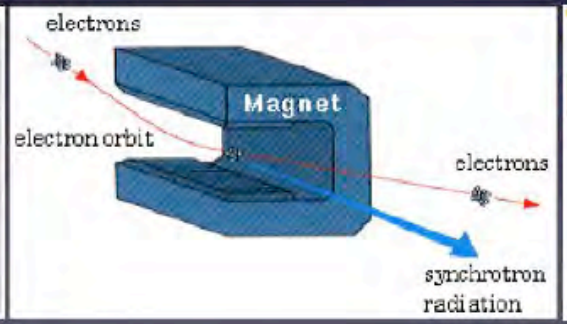
Photon Sources

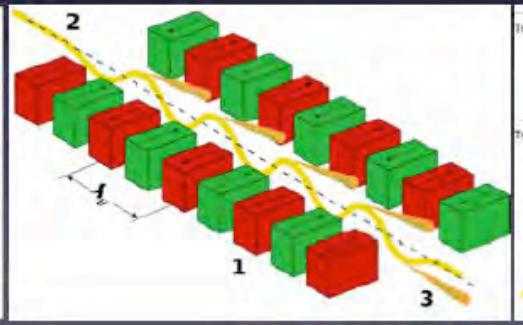
Laboratory source

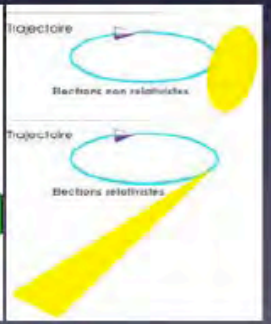


- rare gas discharge lamps
- x-ray tubes
- 10^{14} photons/second

Synchrotron source

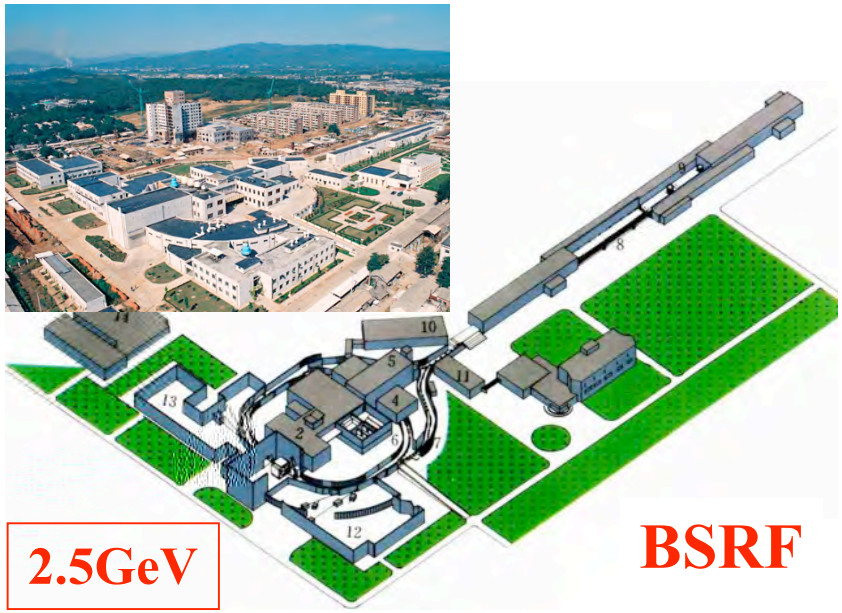






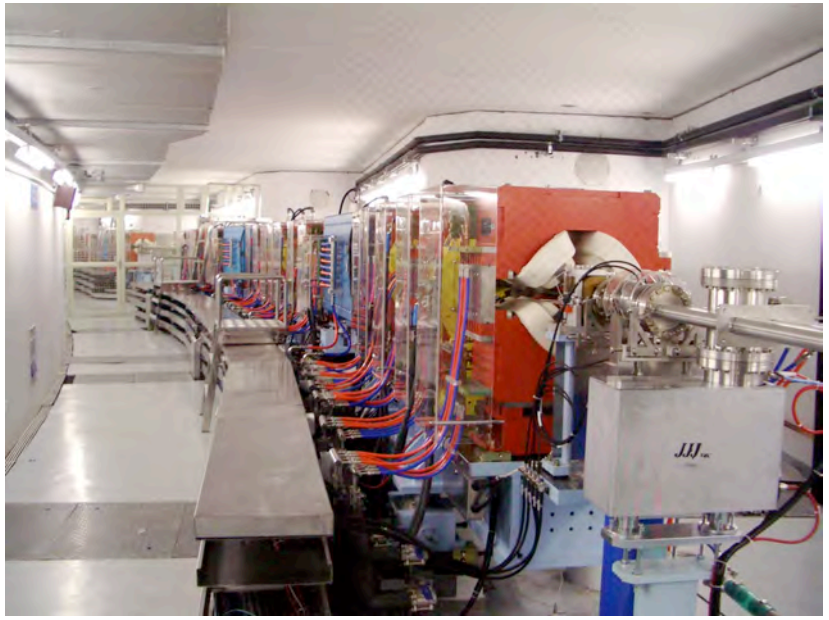
- 10^{15} photons/second

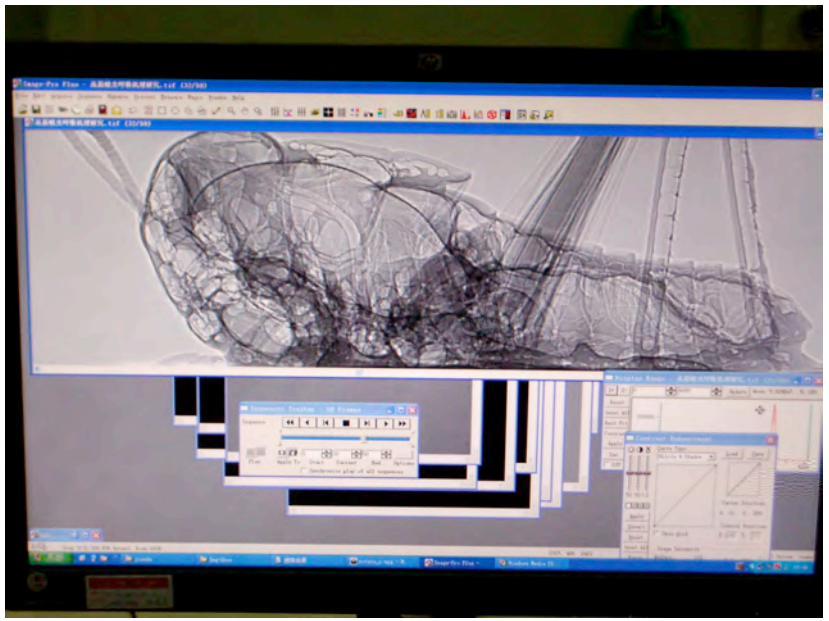

北京
上海
合肥


2.5GeV
BSRF

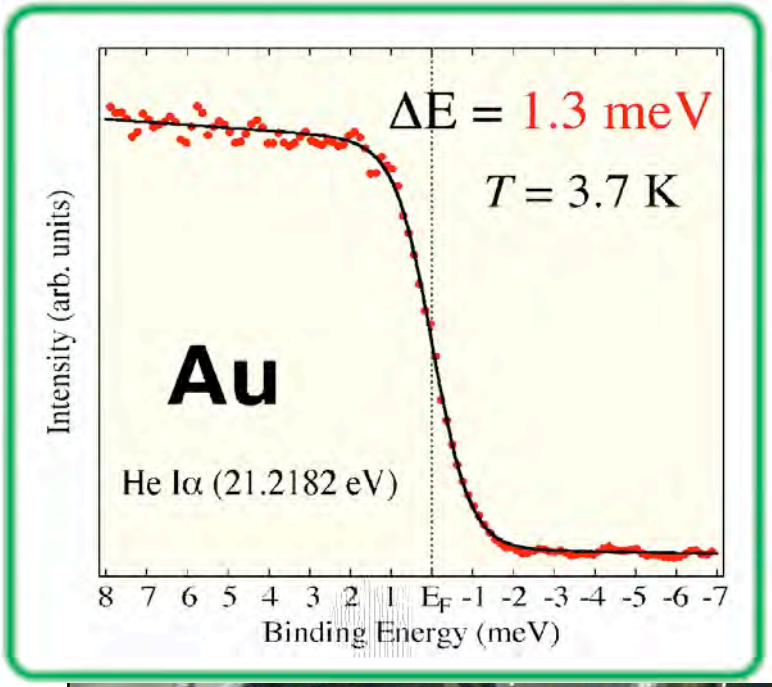

USTC
NSRL
800MeV


3.5GeV





Ultrahigh-resolution ARPES system



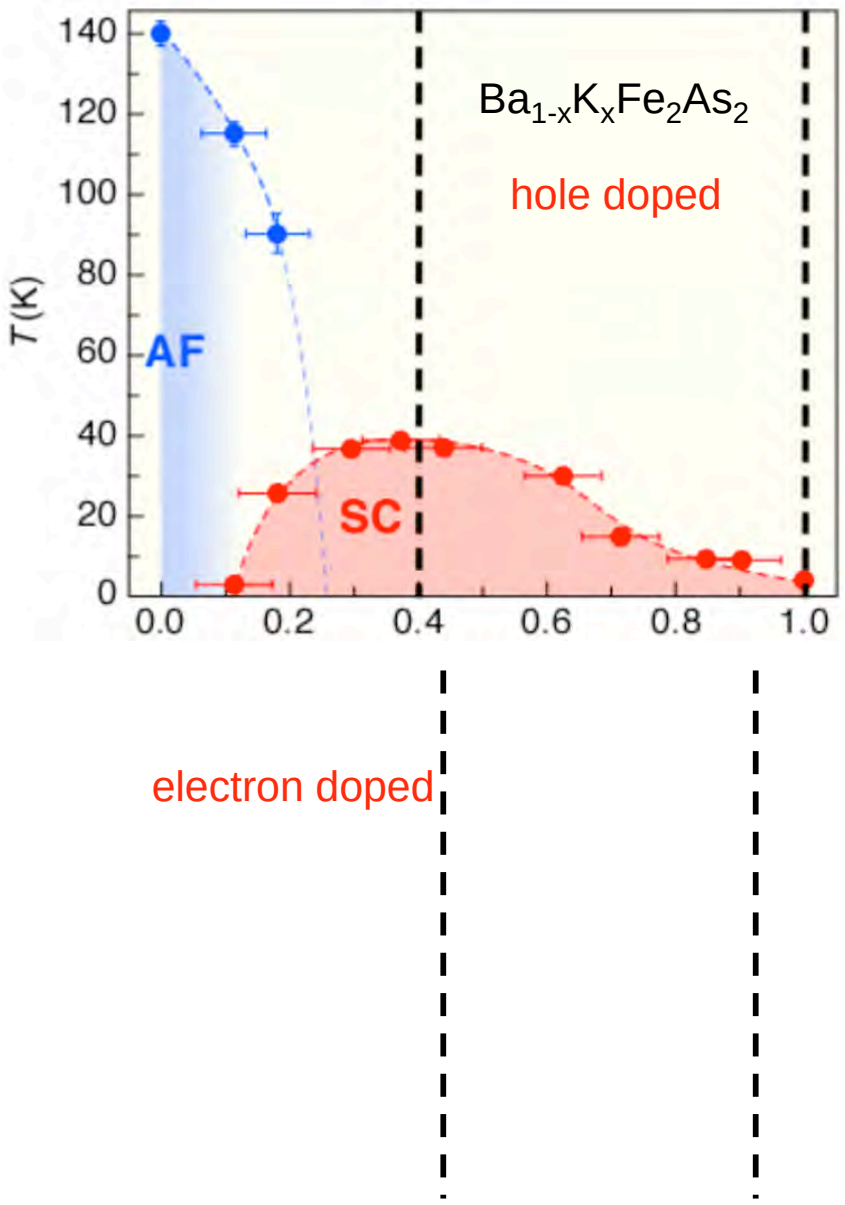
The new iron-based high-T_c (up to 56K) superconductors

LaFeAs $O_{1-x}F_x$ (T_c = 26K)
H. Hosono, Japan
Feb. 23, 2008

SmFeAs $O_{1-x}F_x$ (T_c = 43K)
X.H. Chen

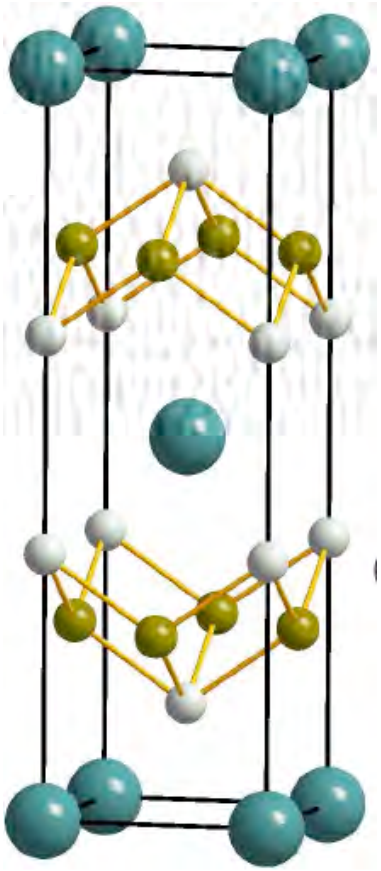
Phase diagram of “122” compounds

$BaFe_2As_2$



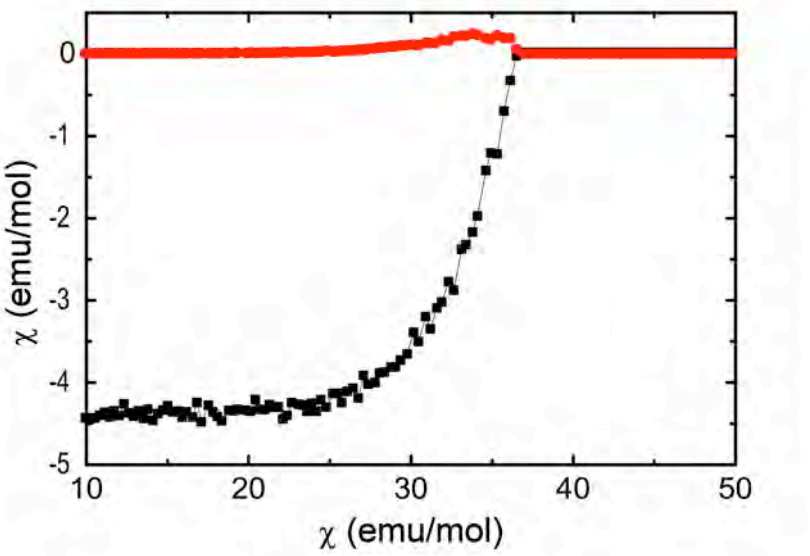
Optimally hole doped samples

Ba^{2+}/K^{+} →

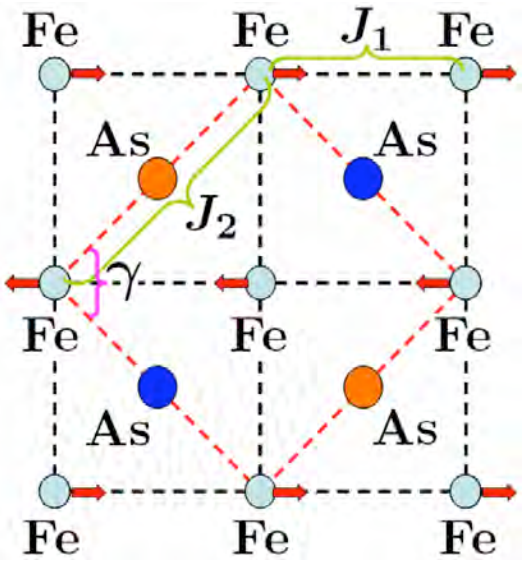


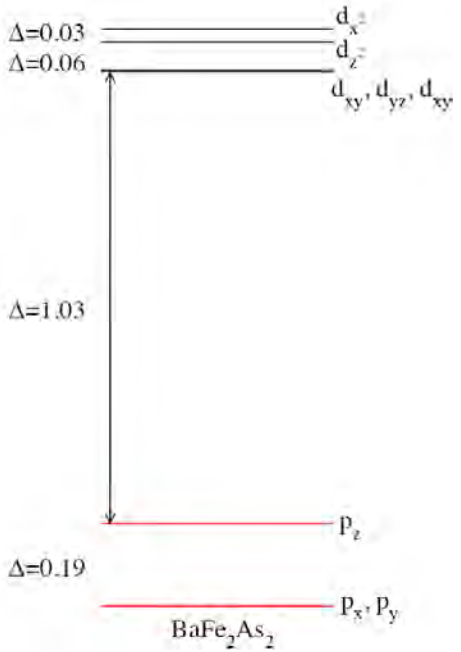
$Ba_{0.6}K_{0.4}Fe_2As_2$

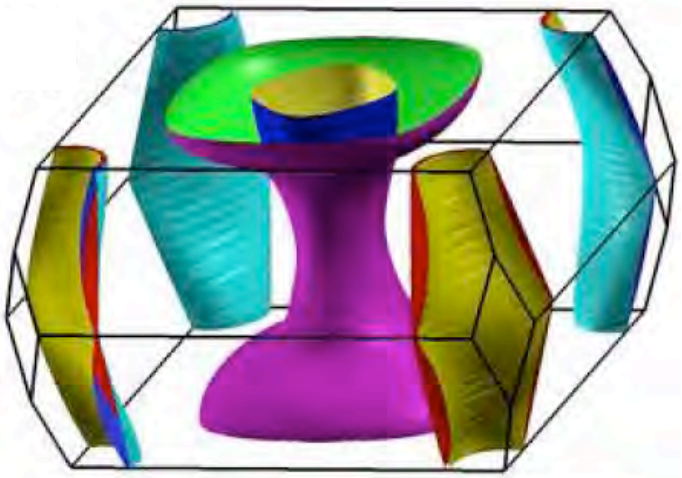
T_c = 37 K

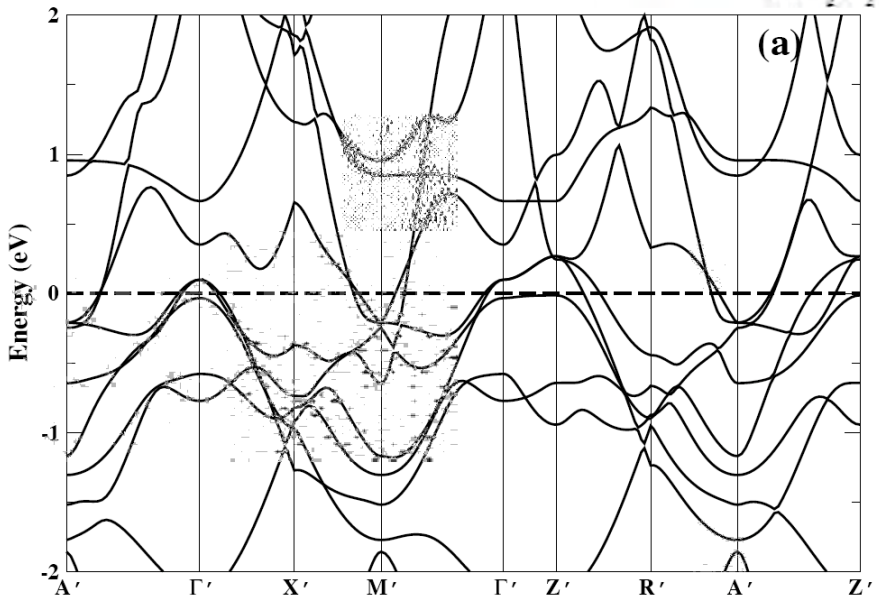


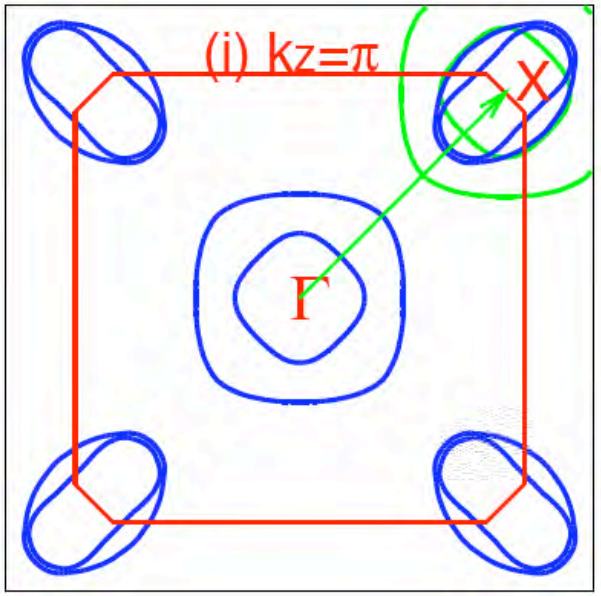
Calculated band structure and Fermi surface



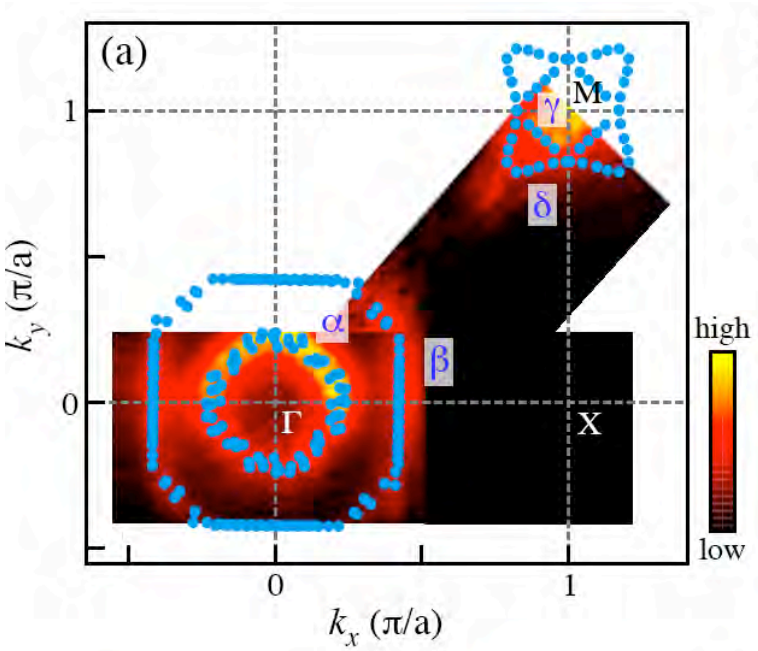


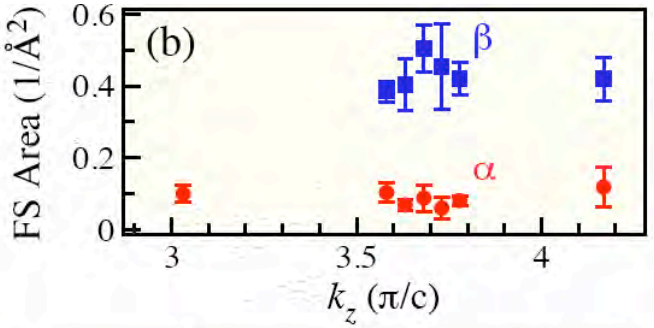




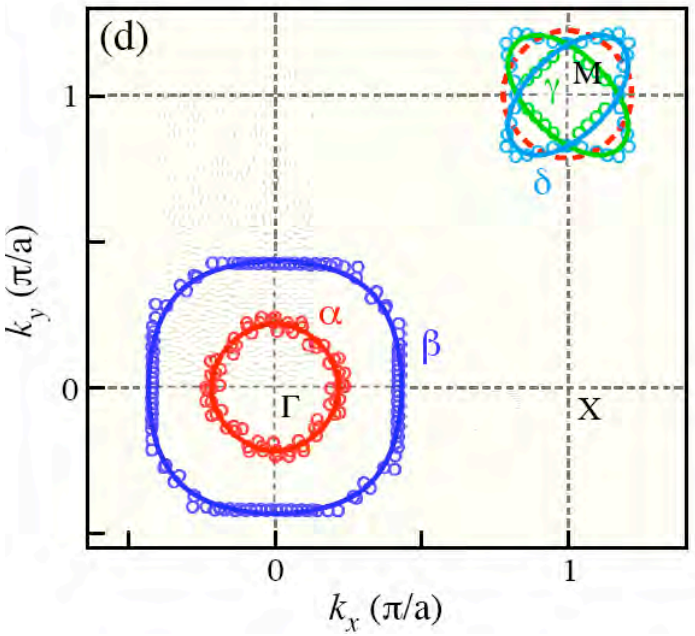


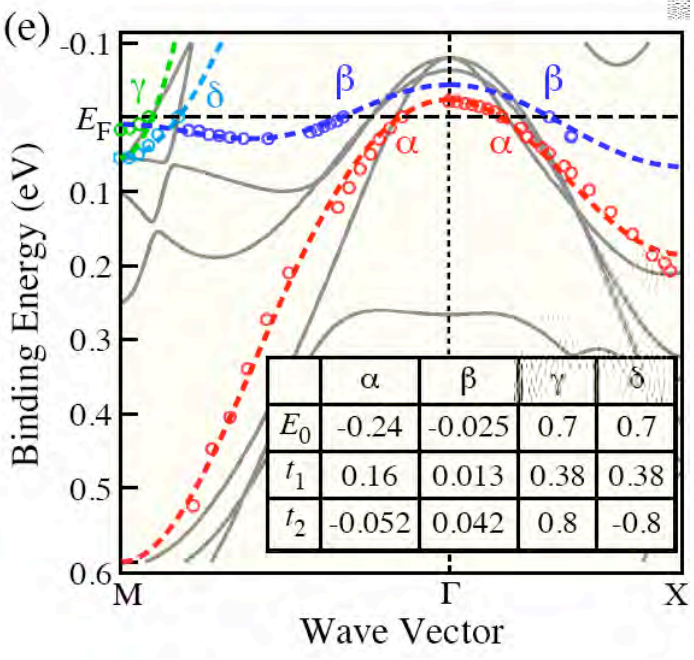
A complete picture of band structure and FS





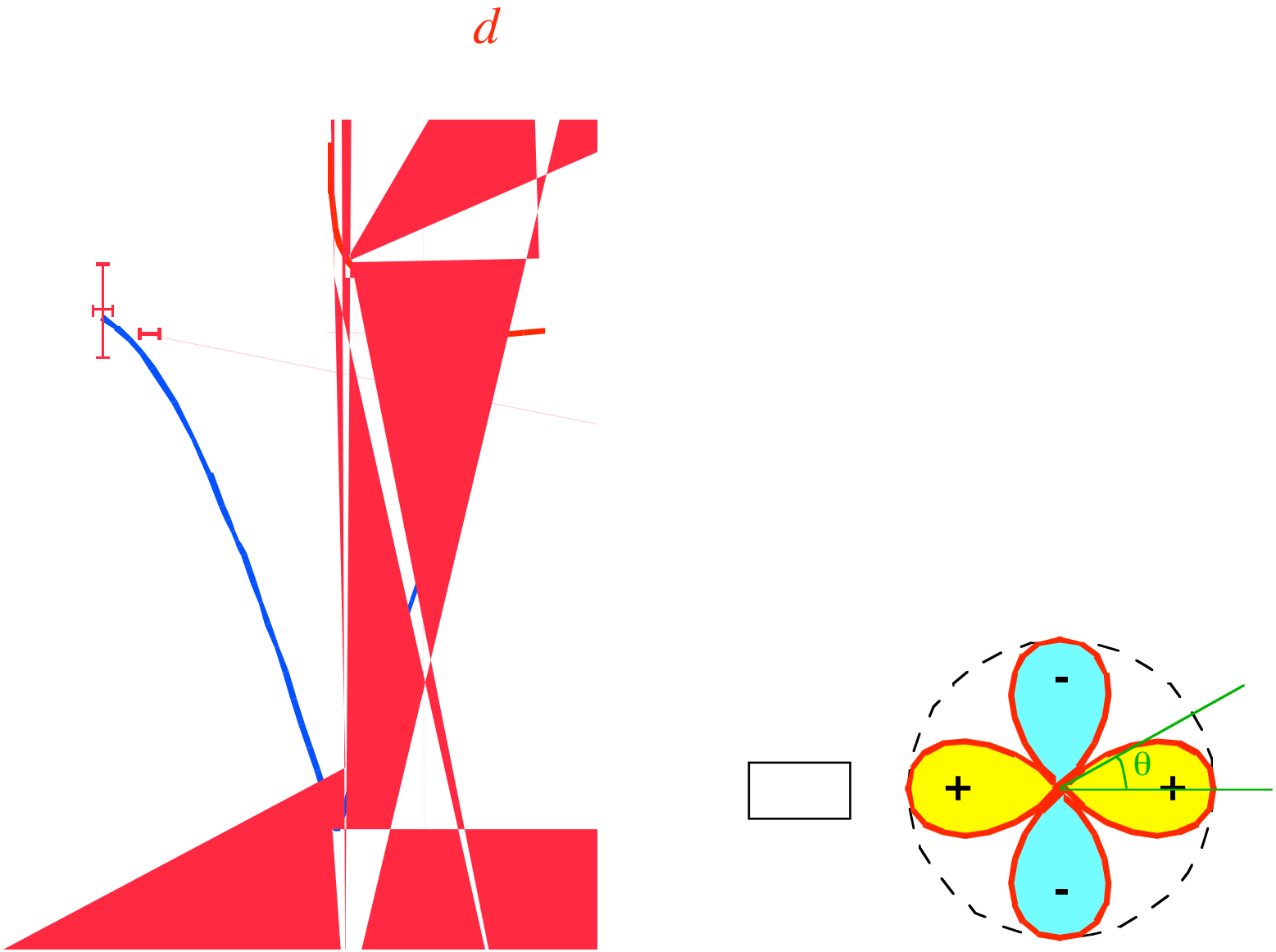
(c)	Fermi velocity (eVÅ)	LDA [5]	
		$k_z=0$	$k_z=\pi$
α (Γ-M)	0.50 ± 0.10	1.70	0.98
β (Γ-M)	0.22 ± 0.04	0.98	0.82
γ (Γ-M)	0.32 ± 0.06	1.48	0.90
δ (Γ-M)	0.48 ± 0.10	4.32	1.48



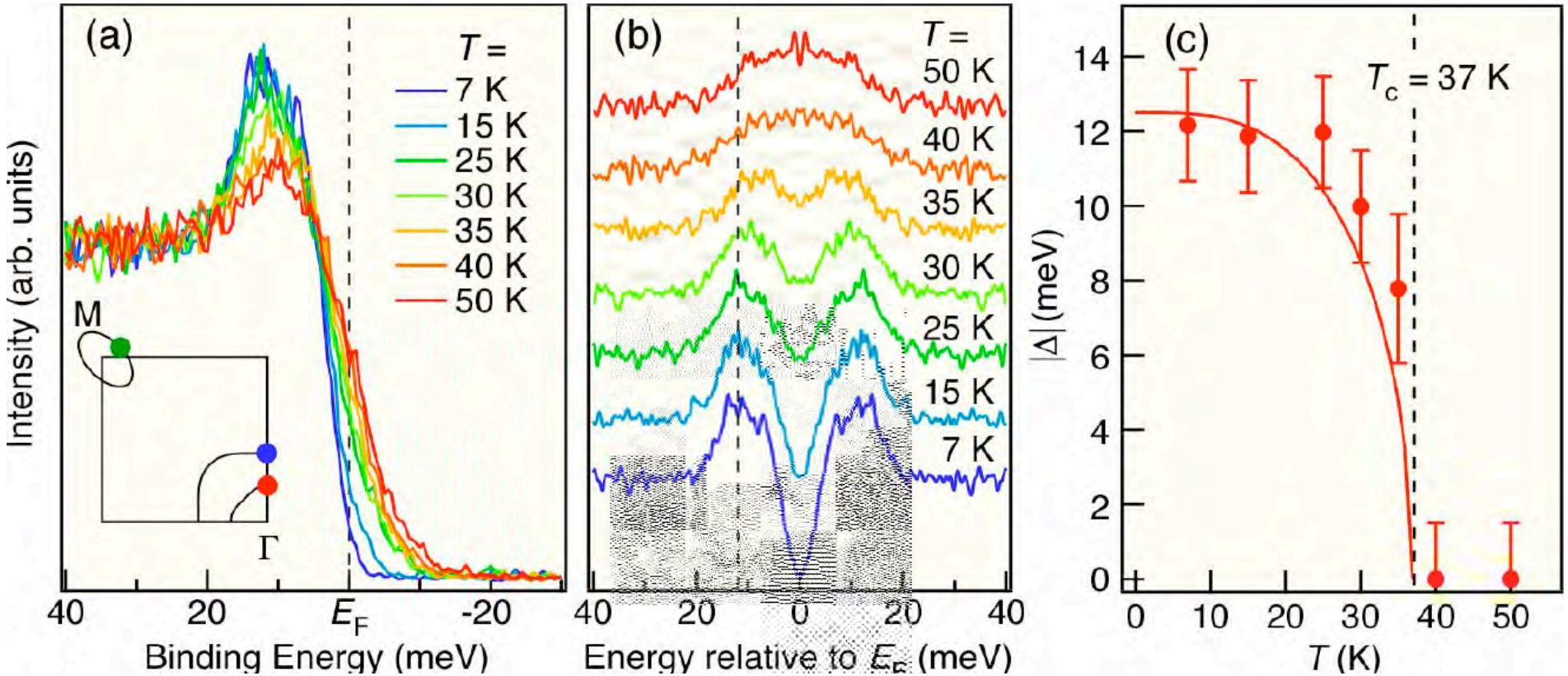


	α	β	γ	δ
E_0	-0.24	-0.025	0.7	0.7
t_1	0.16	0.013	0.38	0.38
t_2	-0.052	0.042	0.8	-0.8

H. Ding *et al.*
arXiv

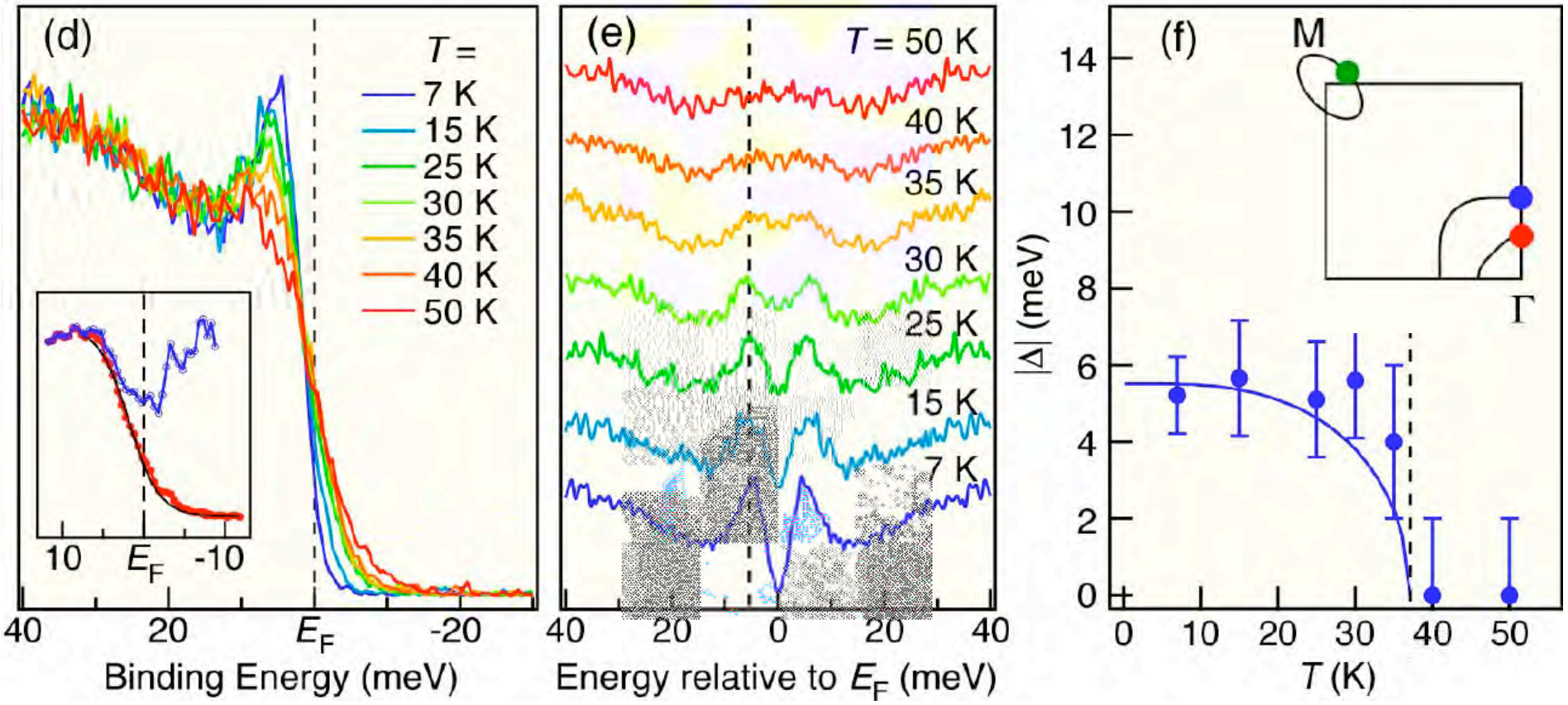

d
θ
+
+
-
-

T-dependence of the SC gap at the α FS



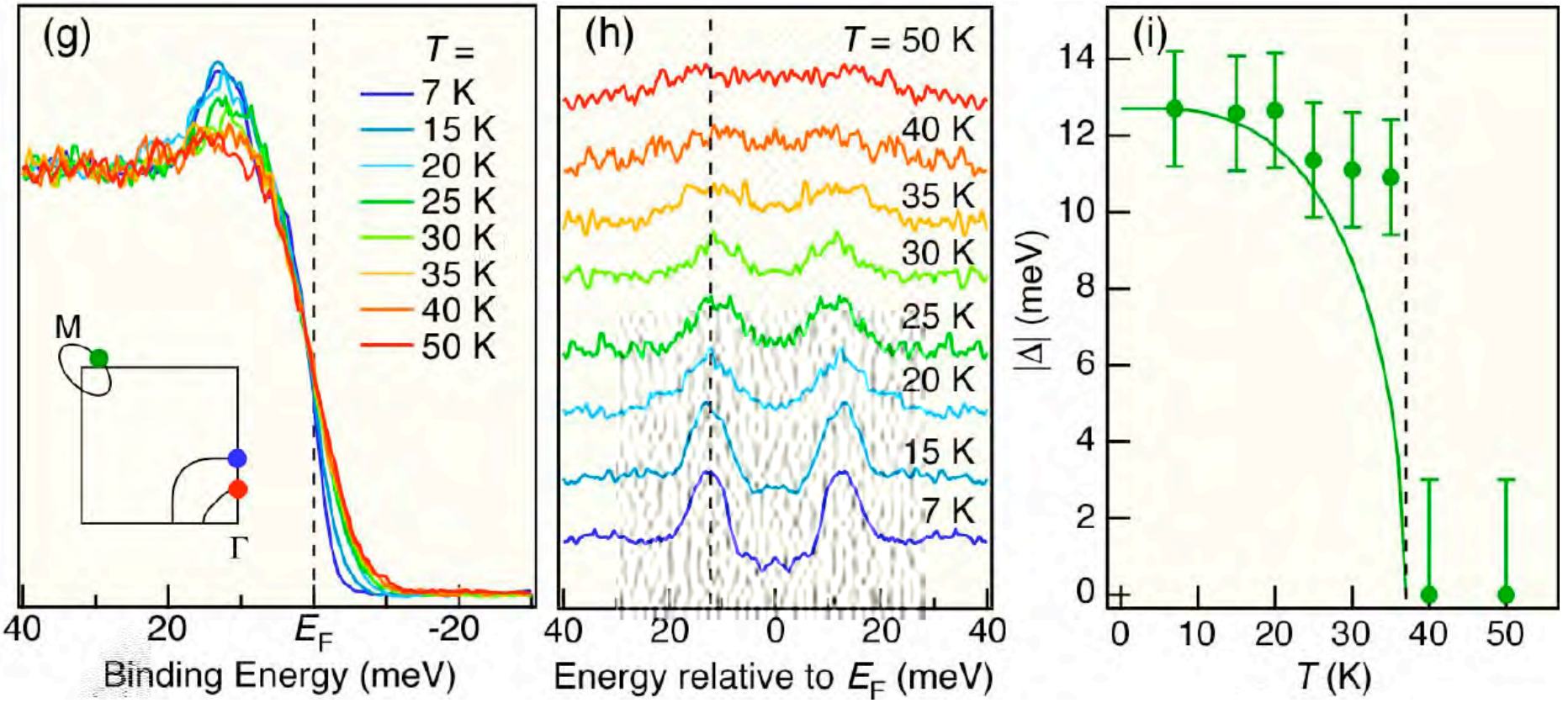
$2\Delta/T_c \sim 7$

T-dependence of the SC gap at the β FS



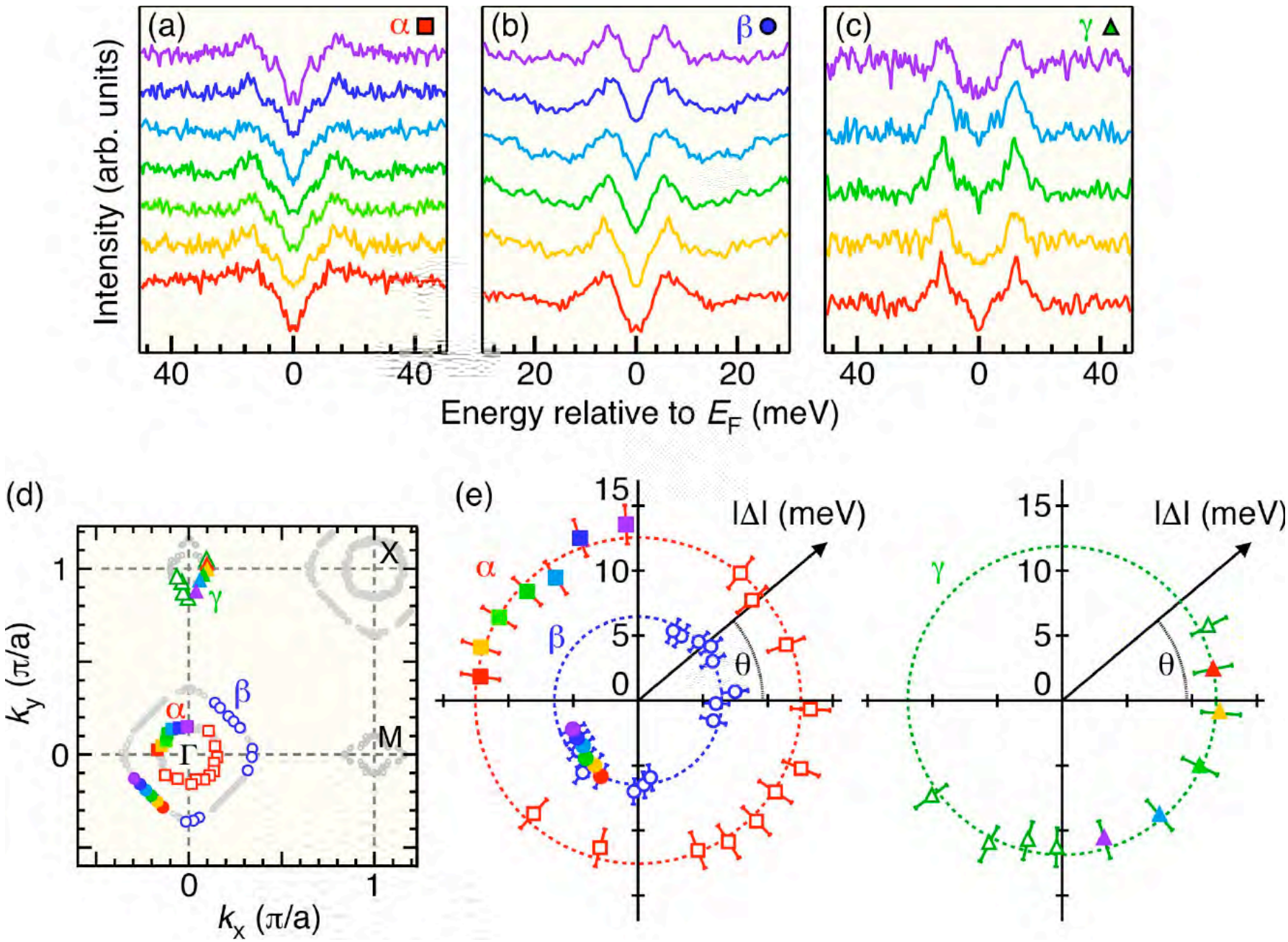
$2\Delta/T_c \sim 3.6$

T-dependence of the SC gap at the γ FS



$2\Delta/T_c \sim 7$

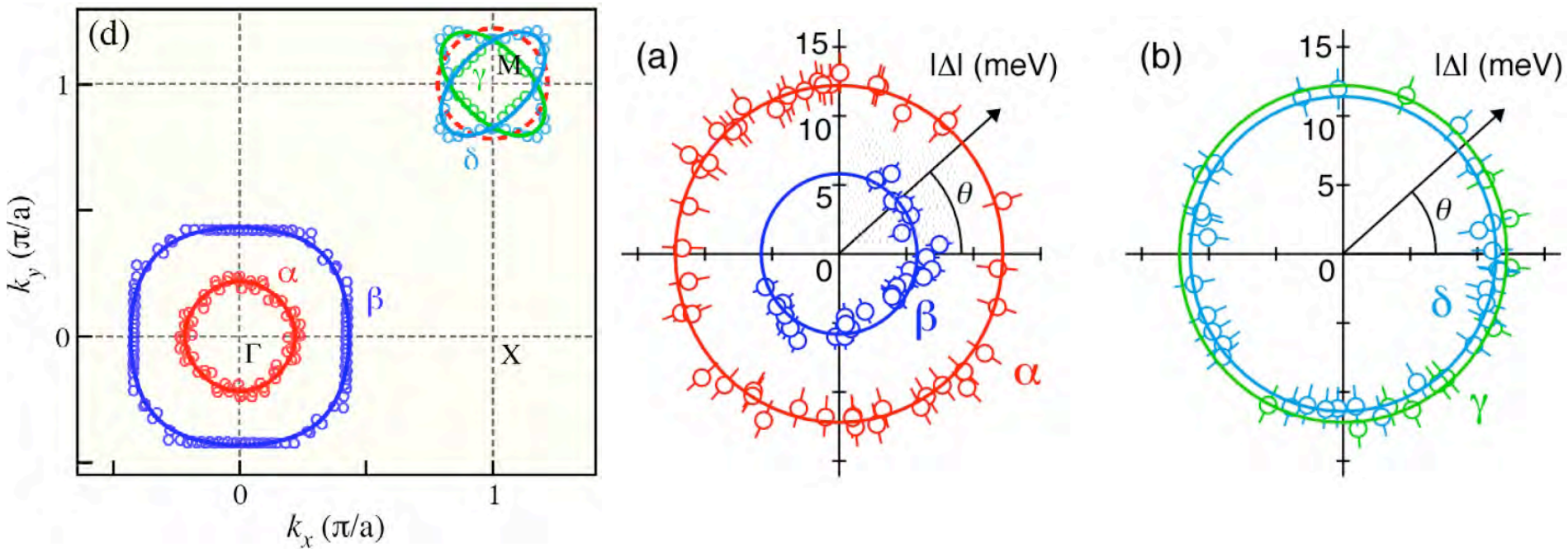
Momentum dependence of the superconducting gap



Fermi surface dependent but isotropic pairing

H. Ding *et al.*, EPL 83, 47001 (2008)

In optimally hole doped samples, good FS nesting between the inner (α) hole pocket and the electron pockets

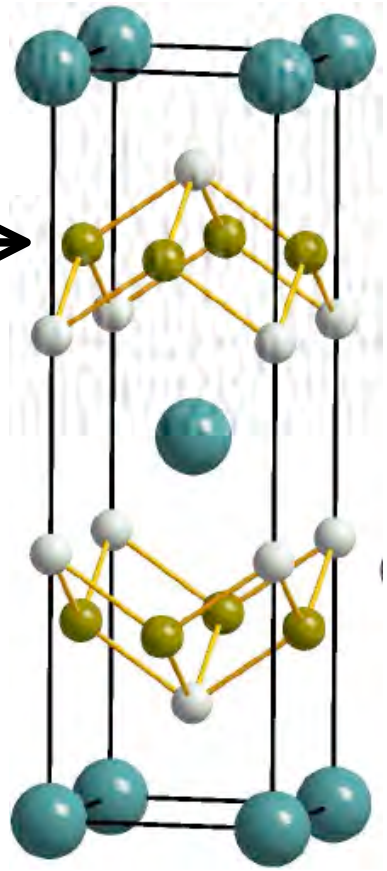


Strong pairing also happens to these FSs!

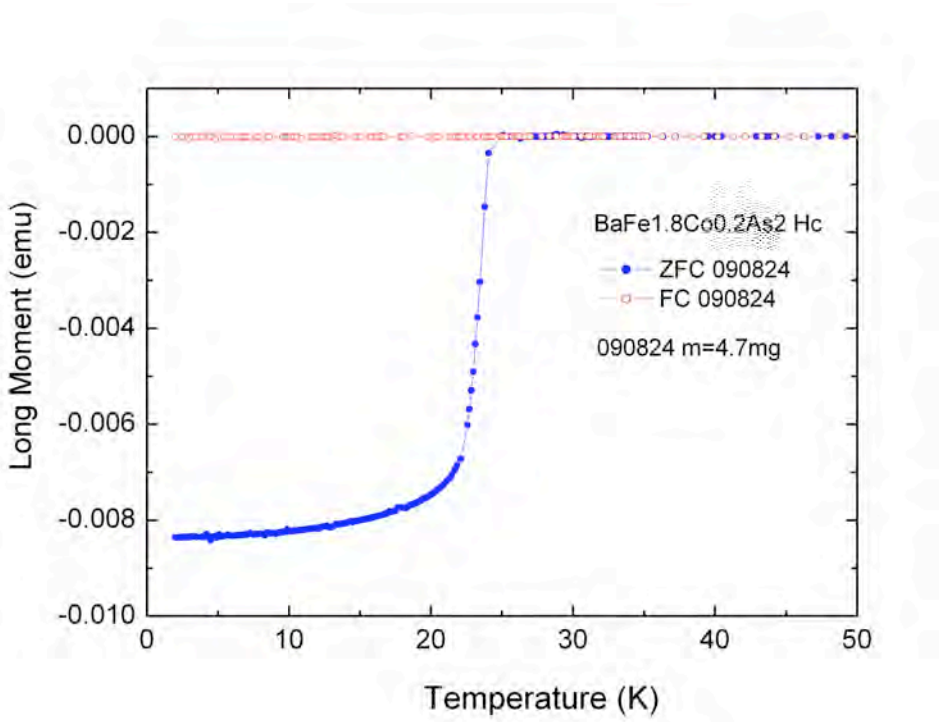
$2\Delta/k_BT_c$ = 7.7, 3.6, 7.7, and 7.2
for α, β, γ, and δ

Optimally electron doped samples

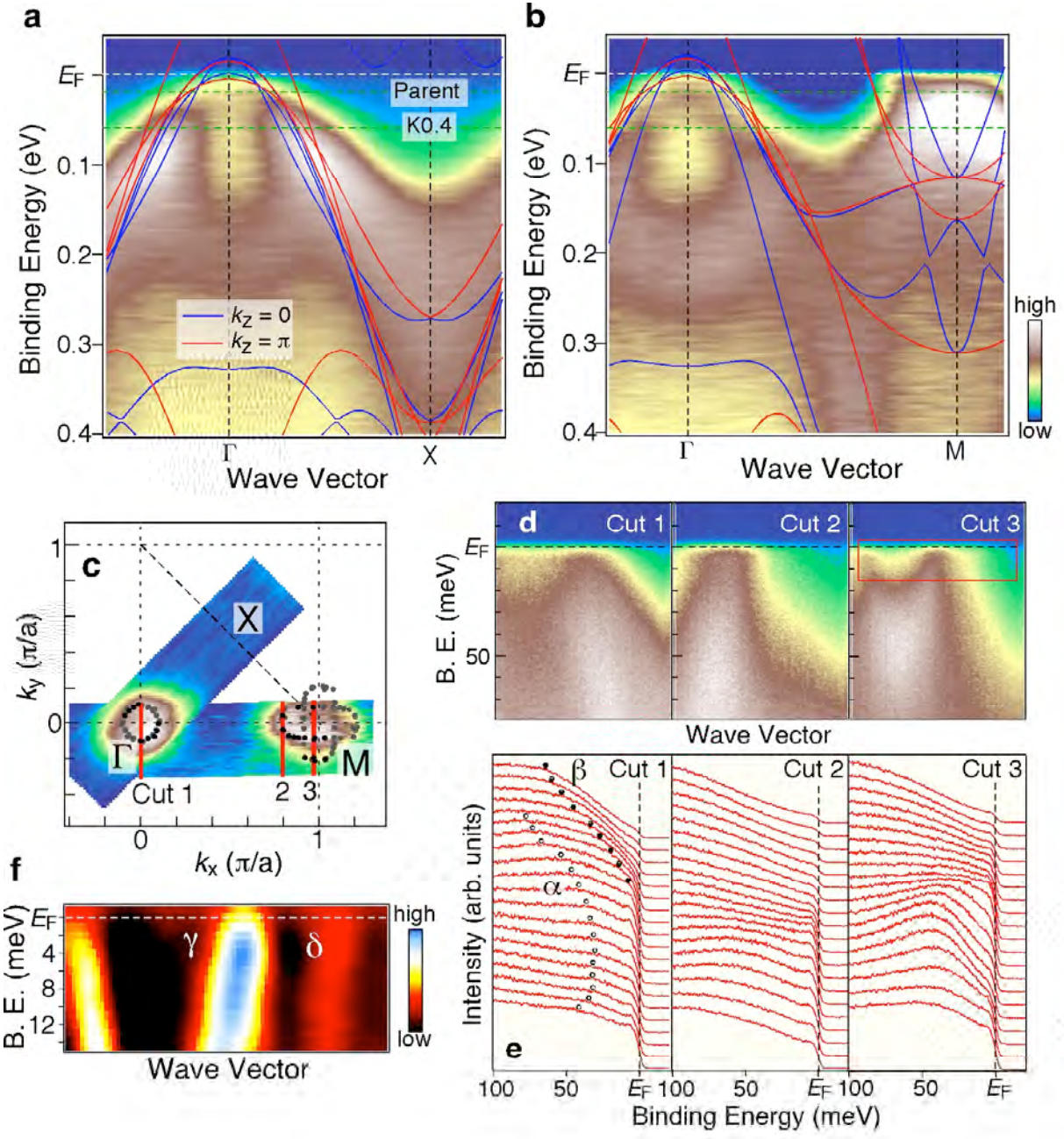
Fe^{2+}/Co^{3+} →



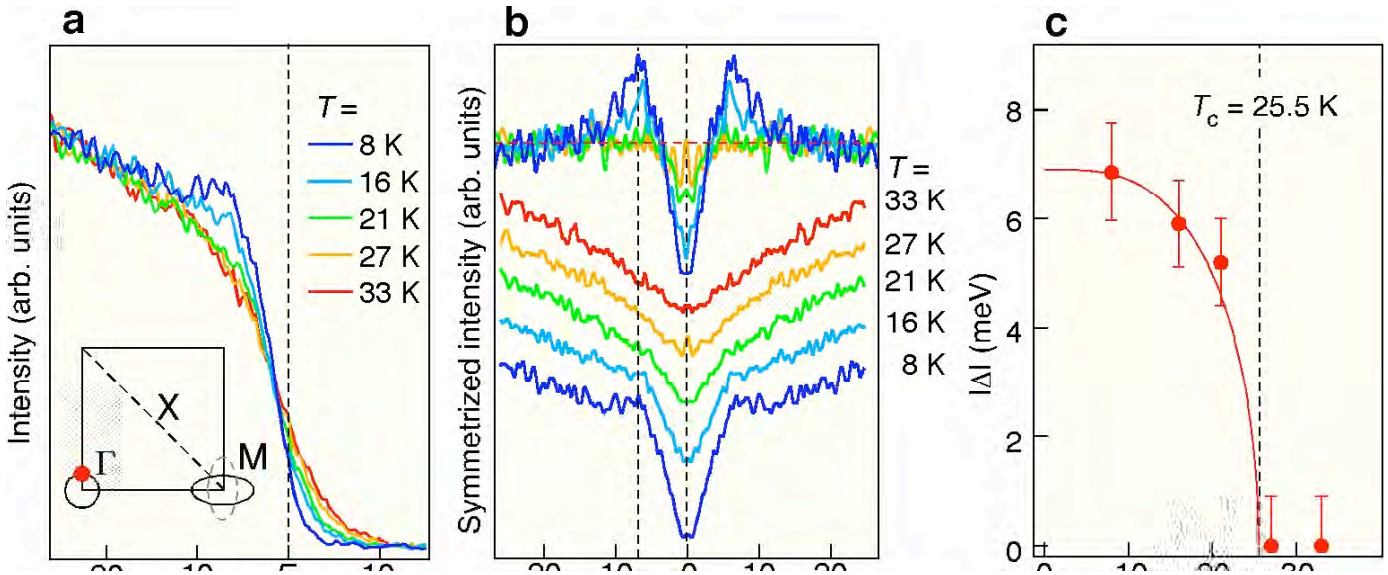
T



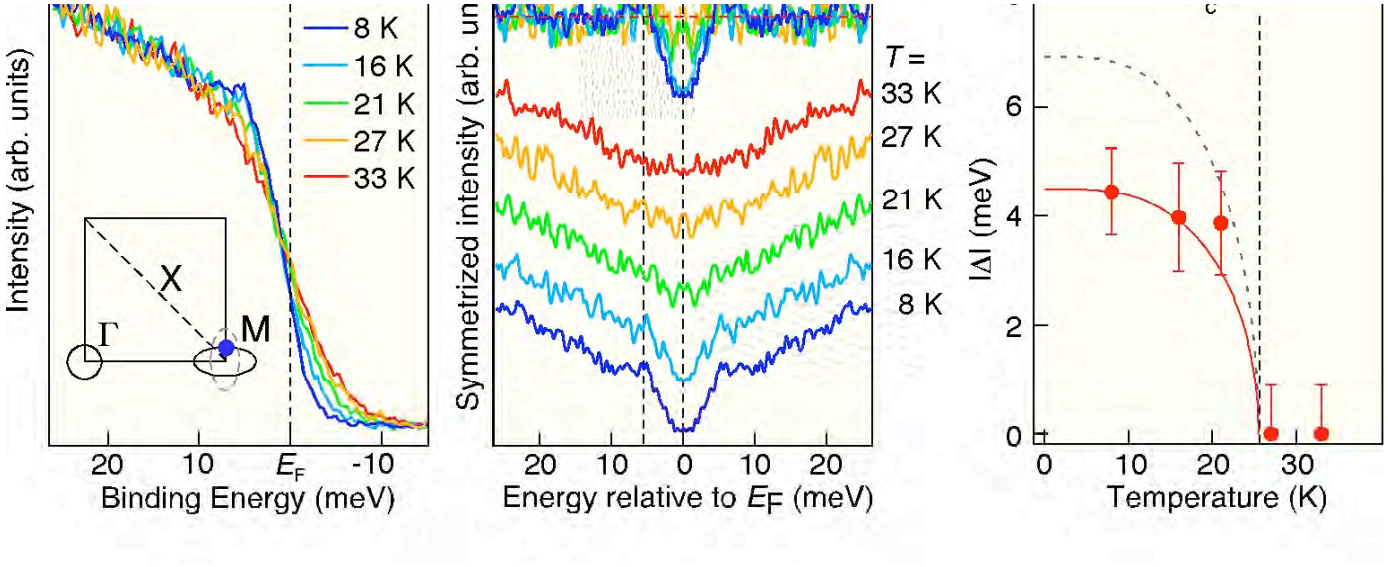
Band structure and FS in $BaFe_{1.85}Co_{0.15}As_2$



Temperature dependence of the SC gaps

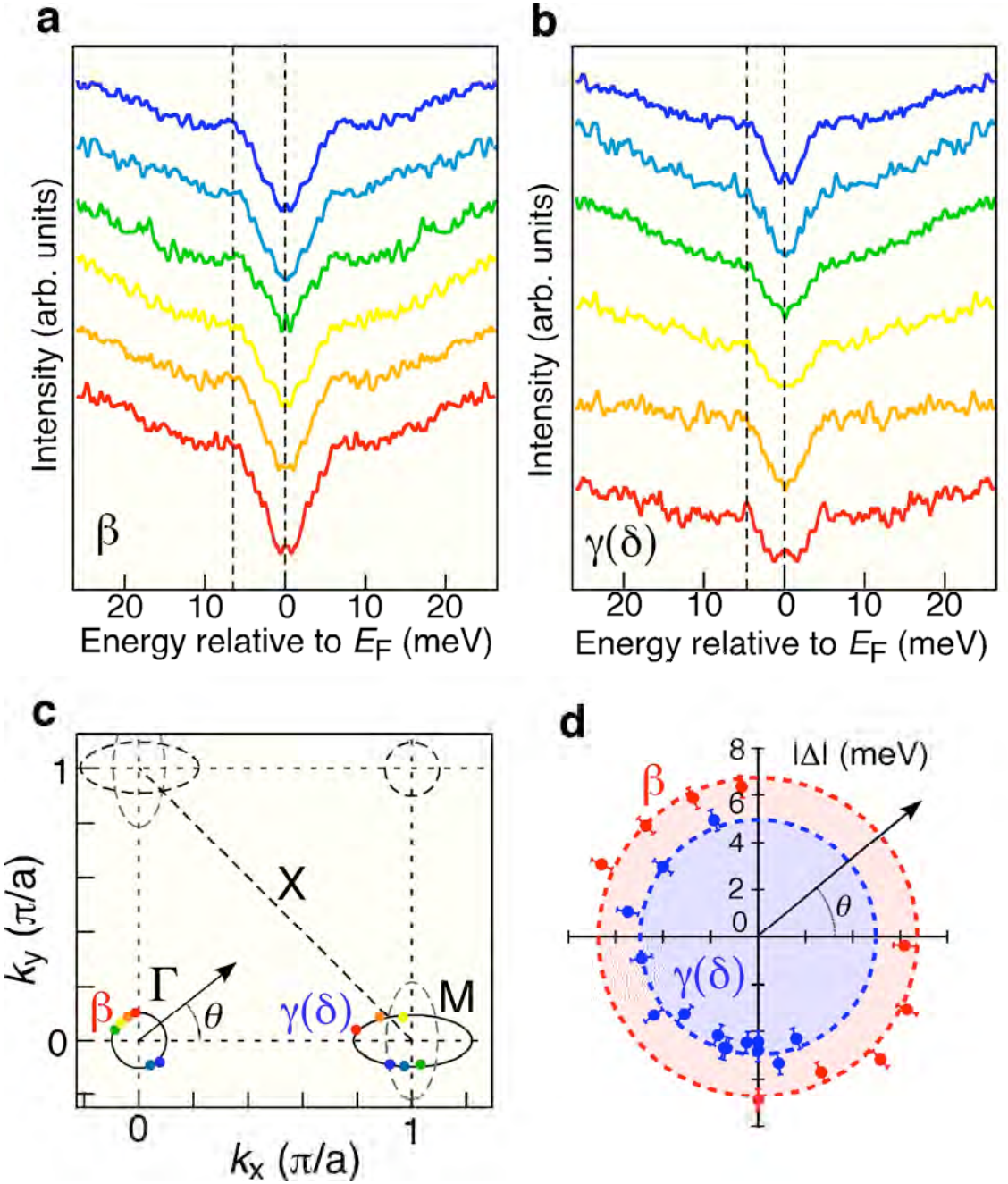


$2\Delta_\beta/k_BT_c = 6$

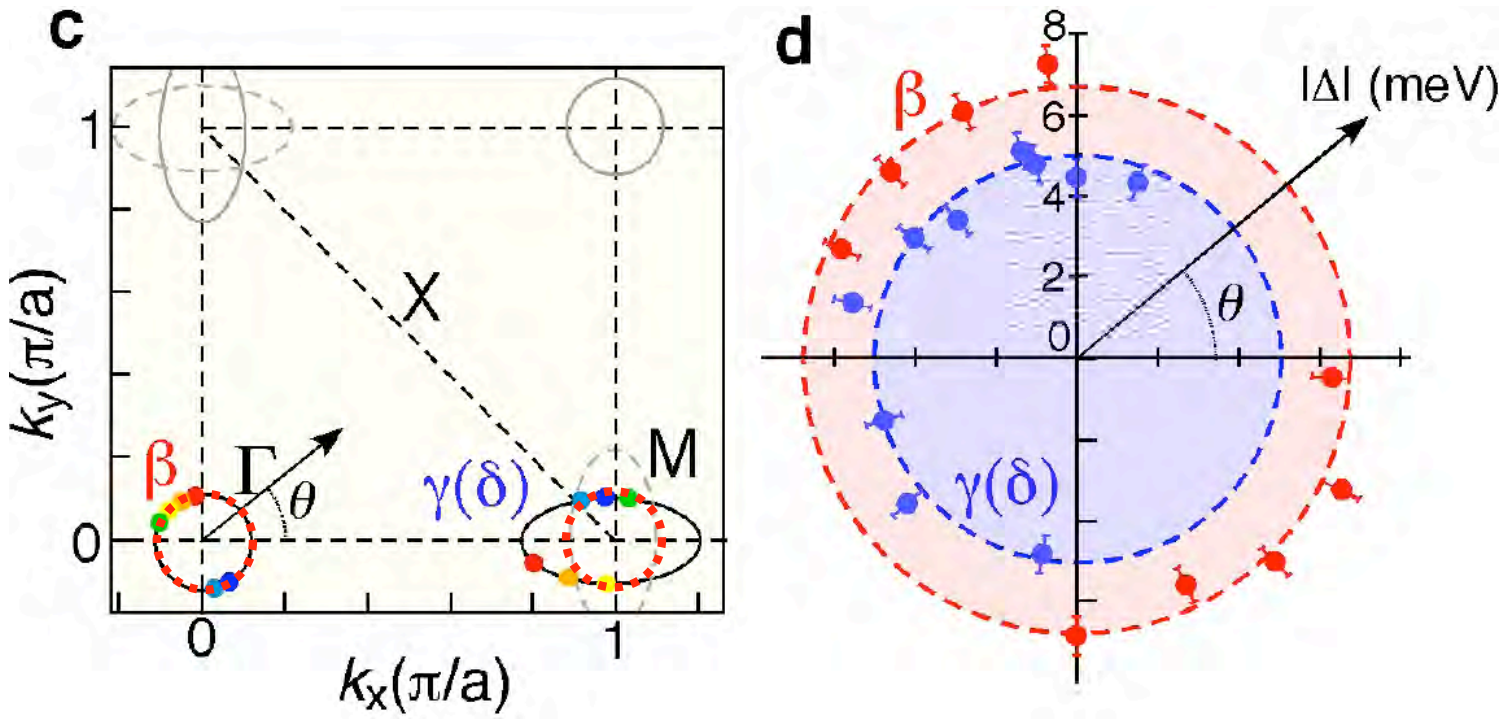


$2\Delta_\delta/k_BT_c = 4.5$

Momentum dependence of the SC gaps



In optimally electron doped samples, good FS nesting between the outer (β) hole pocket and the electron pockets



Strong pairing also happens to these FSs!

$2\Delta/k_BT_c = 6,\ 4.5$
for $\beta,\ \gamma(\delta)$

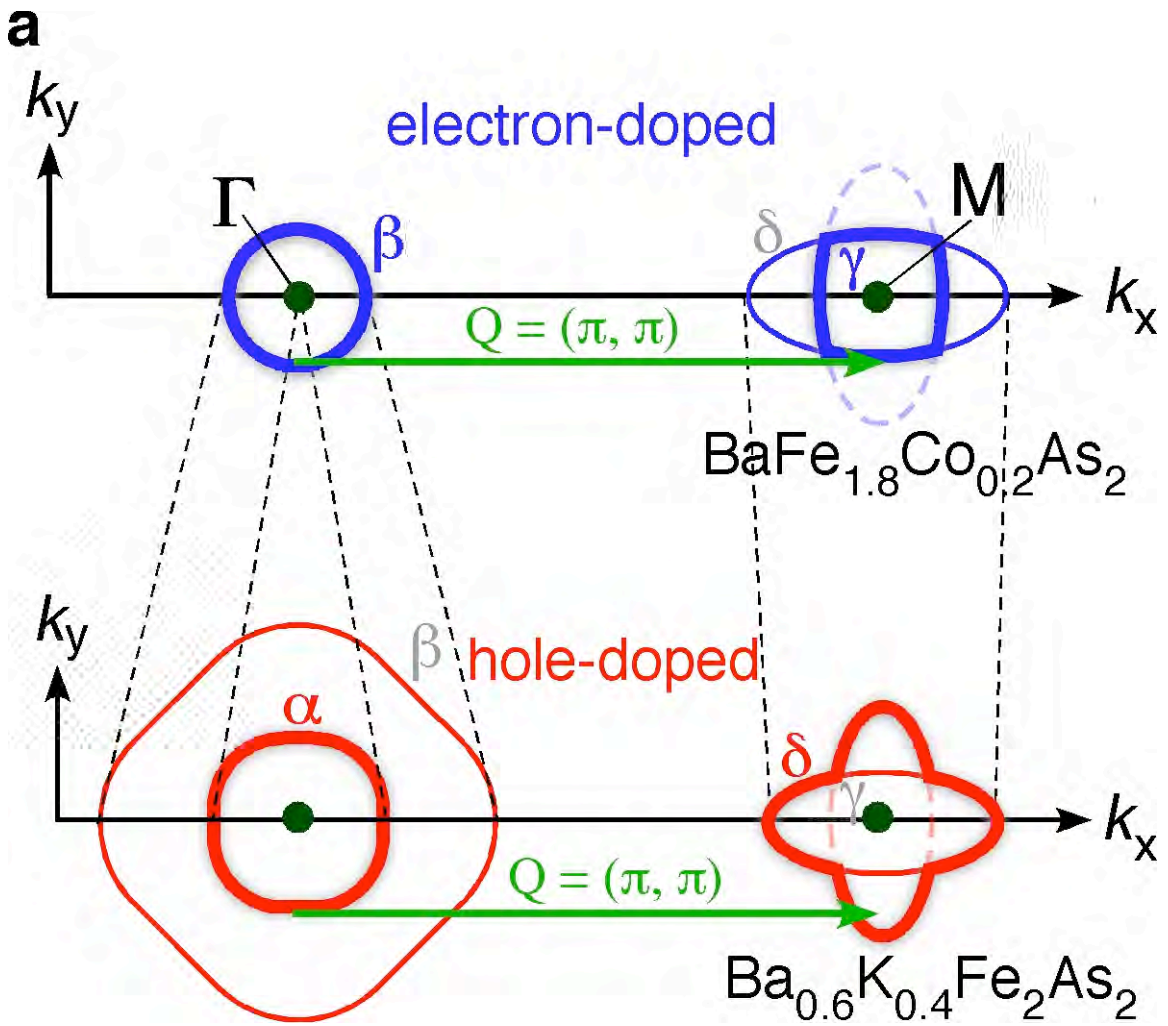
K. Terashima *et al.*, arXiv: 0812.3704

FS nesting induced strong pairing

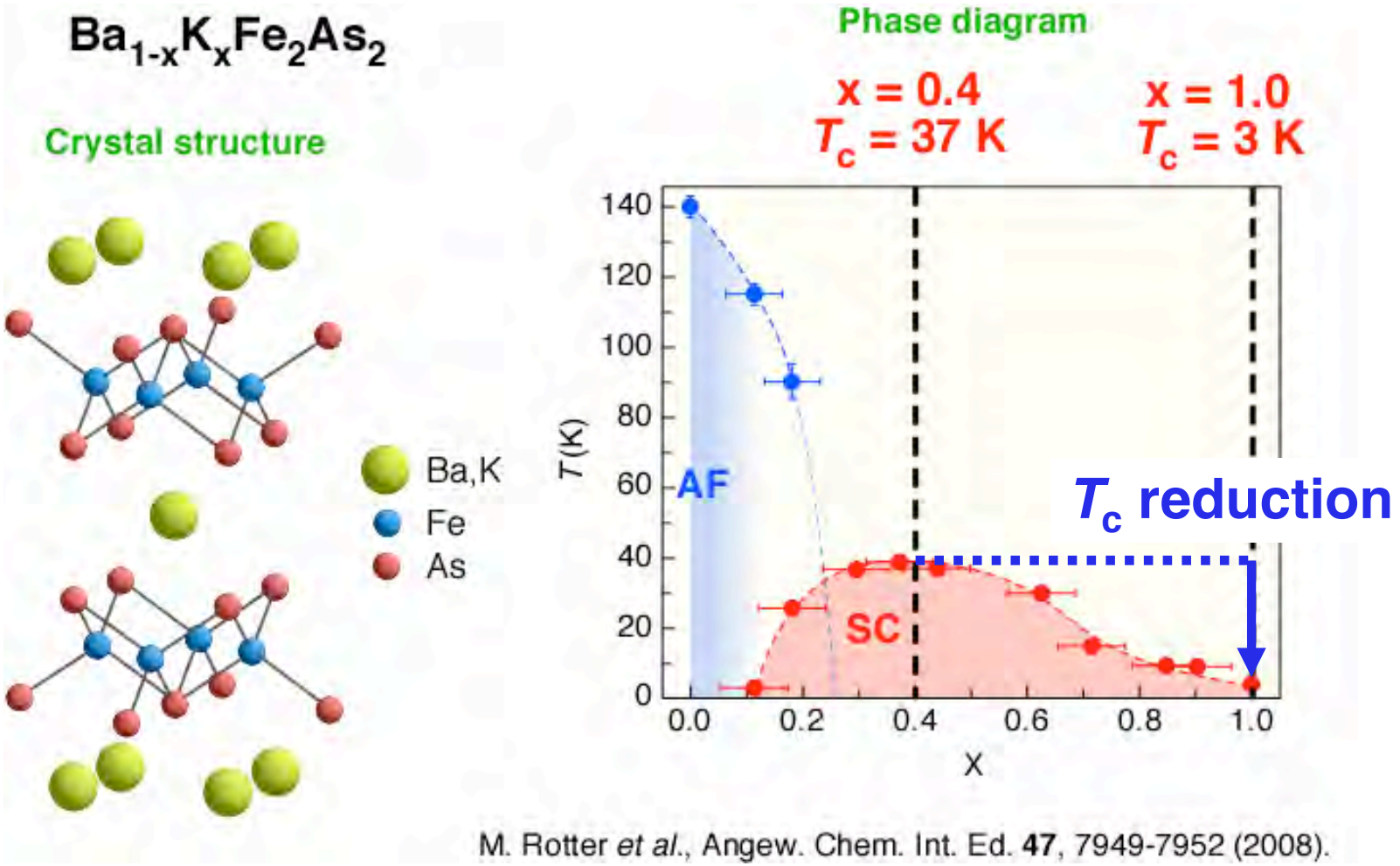
$2\Delta_\beta/k_BT_c = 6$

$2\Delta_\beta/k_BT_c = 3.6$

$2\Delta_\alpha/k_BT_c = 7.7$

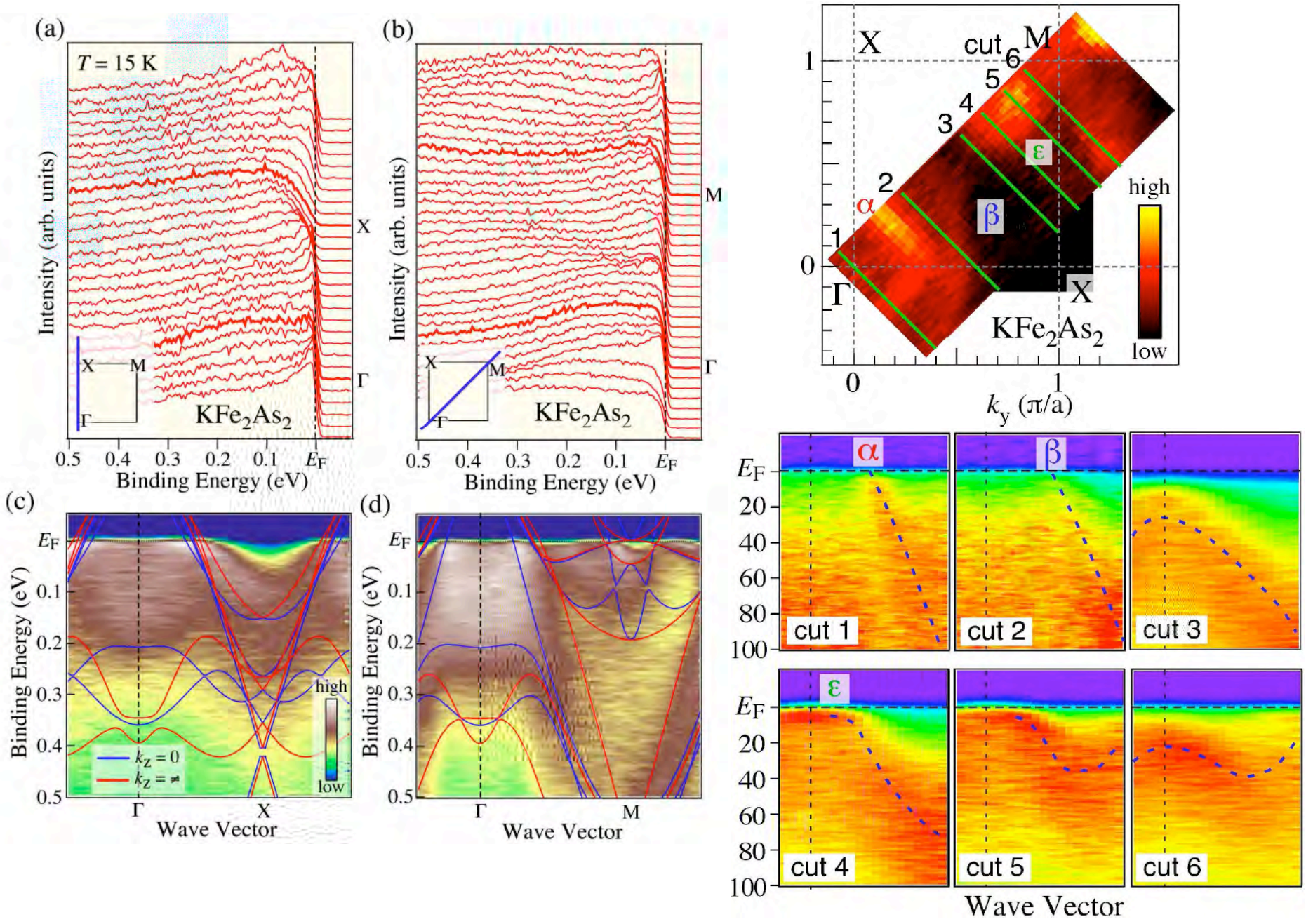


Collapse of T_c in heavily hole doped samples

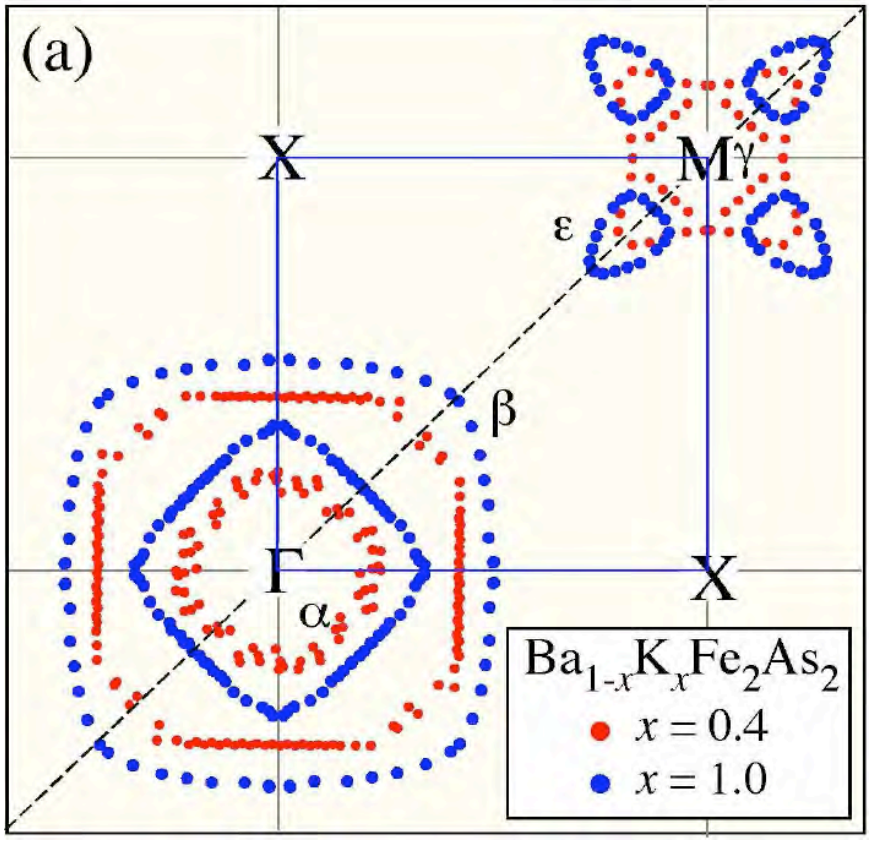


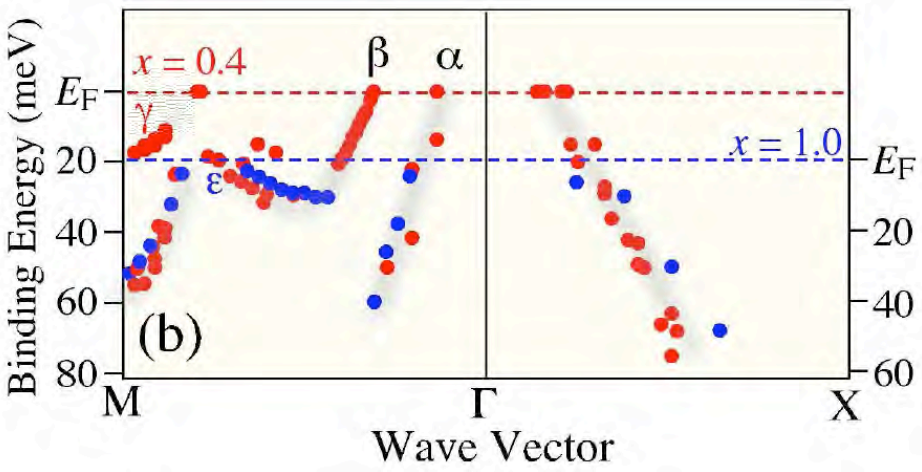
M. Rotter *et al.*, Angew. Chem. Int. Ed. **47**, 7949-7952 (2008).

Band Structure and Fermi Surface of KFe_2As_2



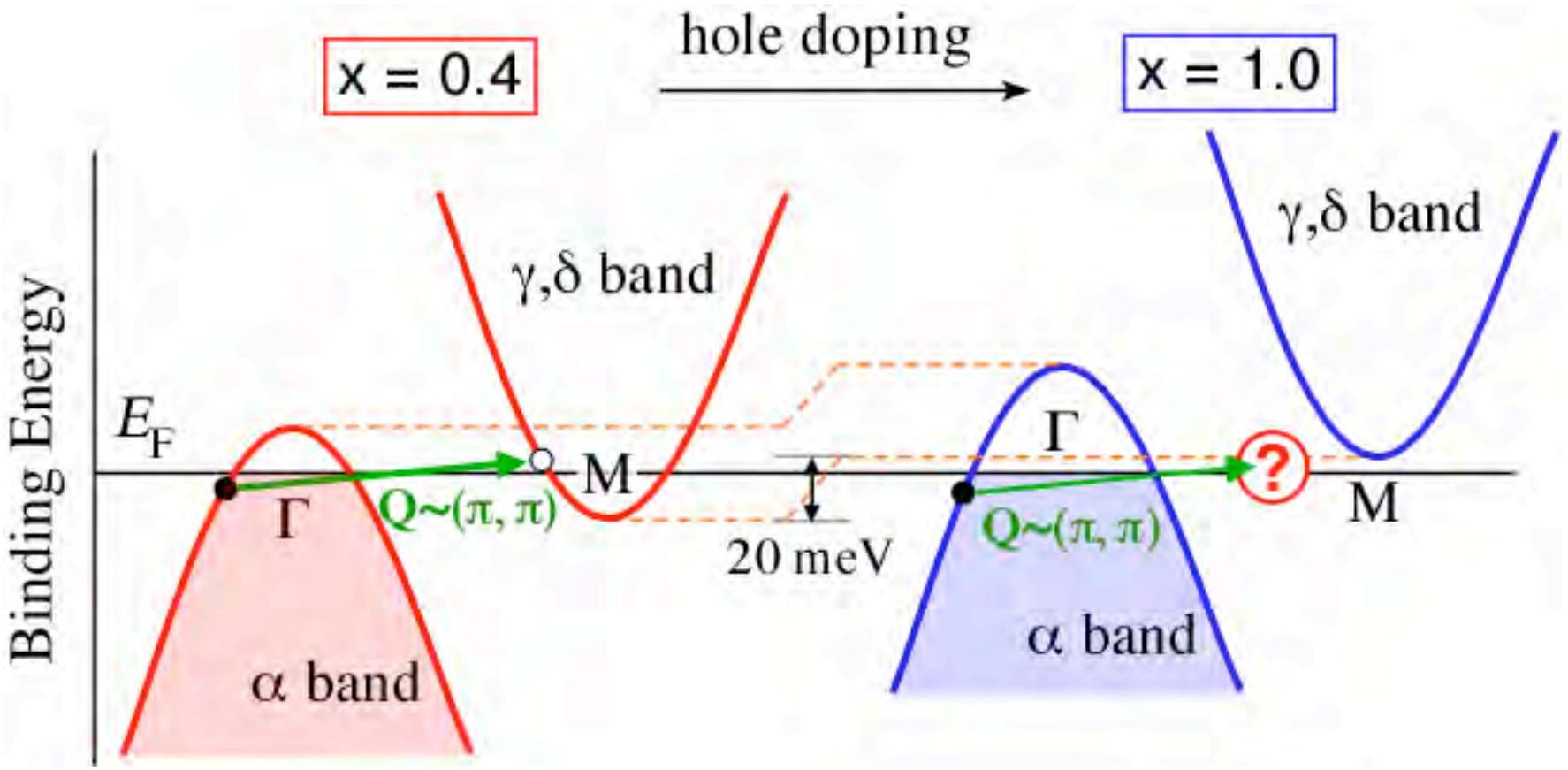
Doping evolution of Fermi surfaces of $Ba_{1-x}K_xFe_2As_2$





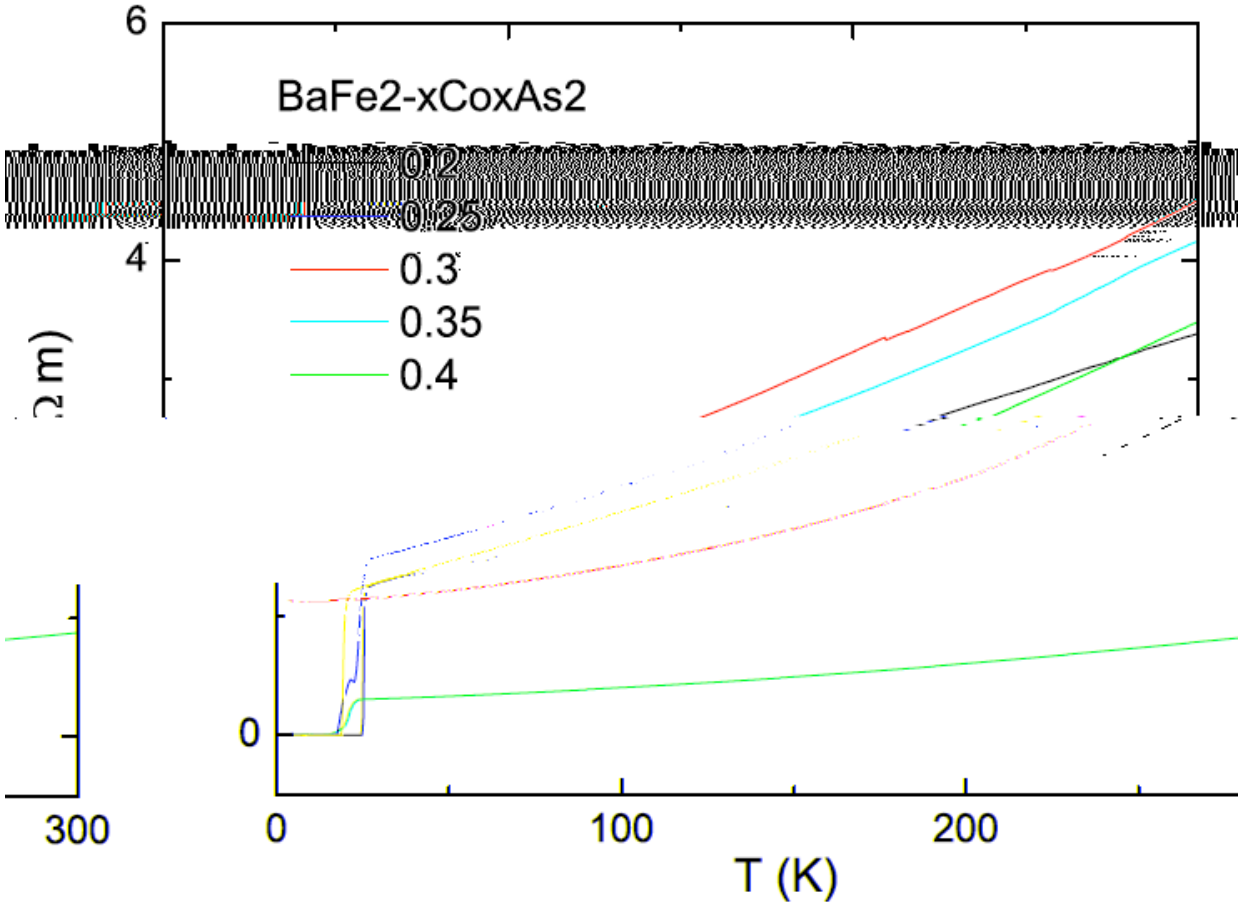
T. Sato *et al.*, arXiv: 0810.3047

Disappearance of electron FS pockets ⟷ collapse of T_c



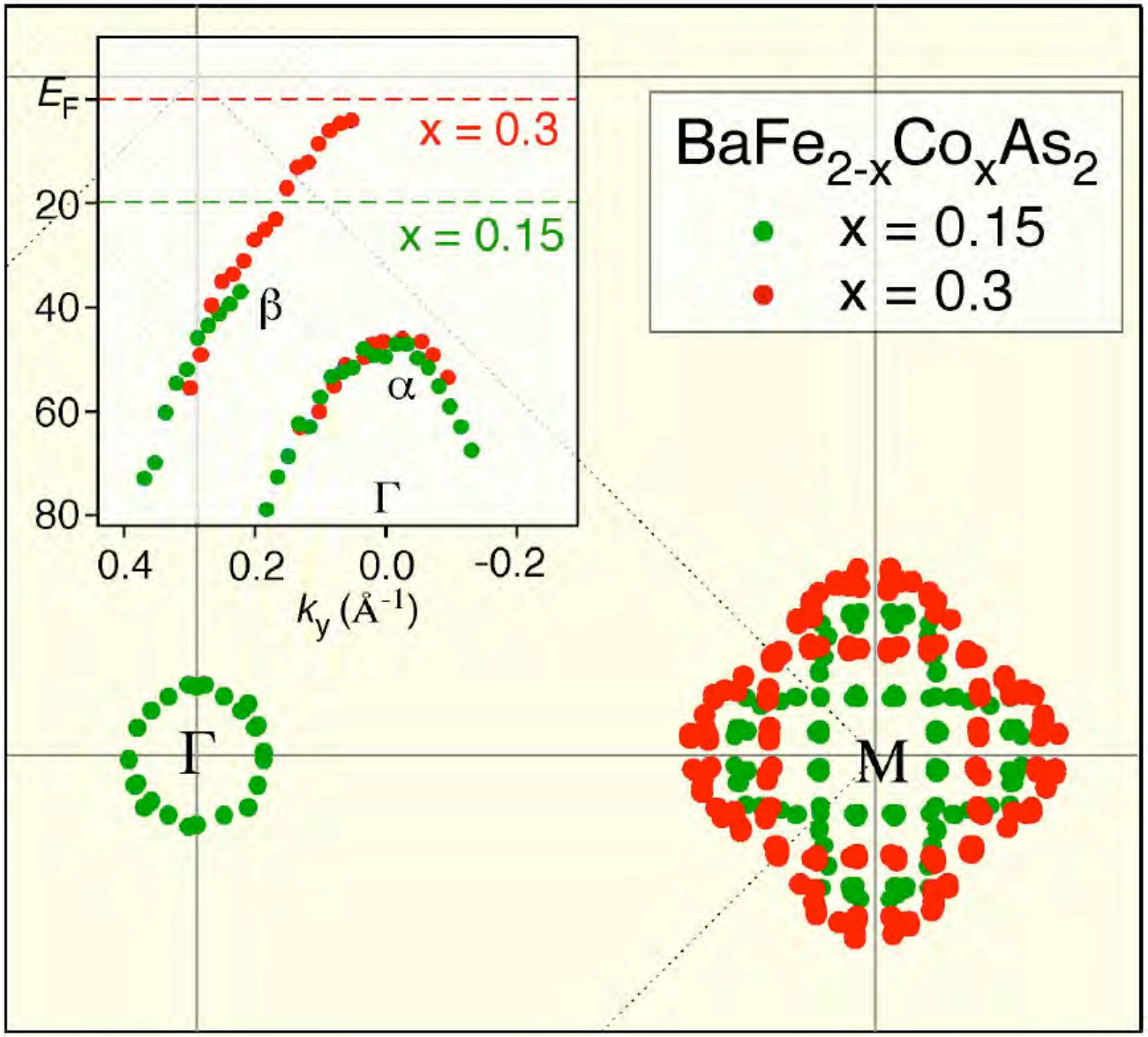
· **Interband scattering via Q_{AF}**

Disappearance of T_c in heavily electron doped samples



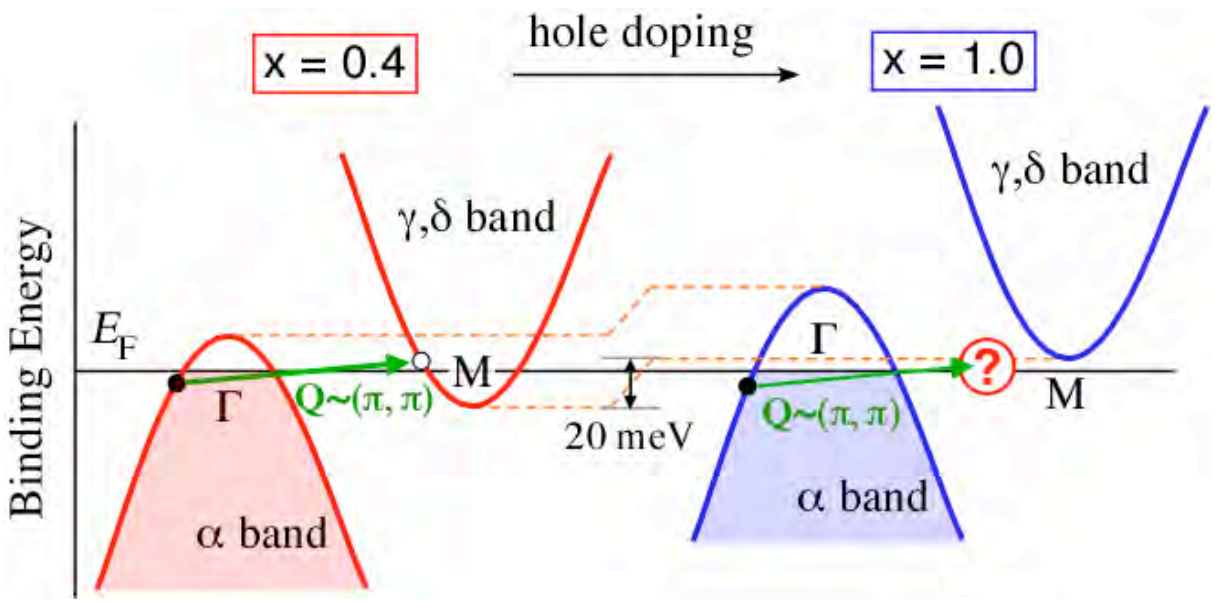
T

Doping evolution of Fermi surfaces of $BaFe_{2-x}Co_xAs_2$



Disappearance of hole FS pockets $\longleftrightarrow$ collapse of T_c

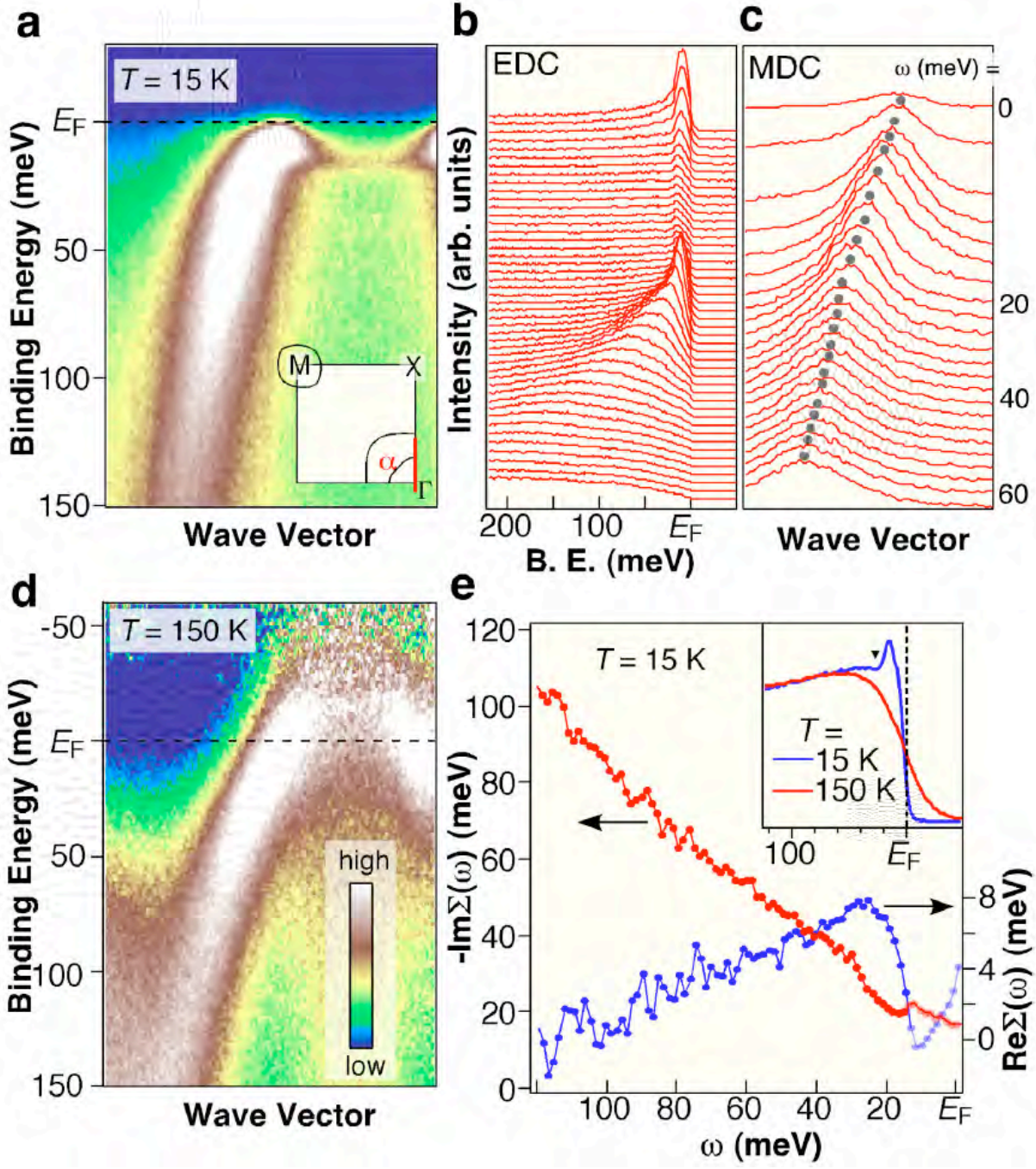
Vanish of interpocket Q_{AF} ⟷ collapse of T_c

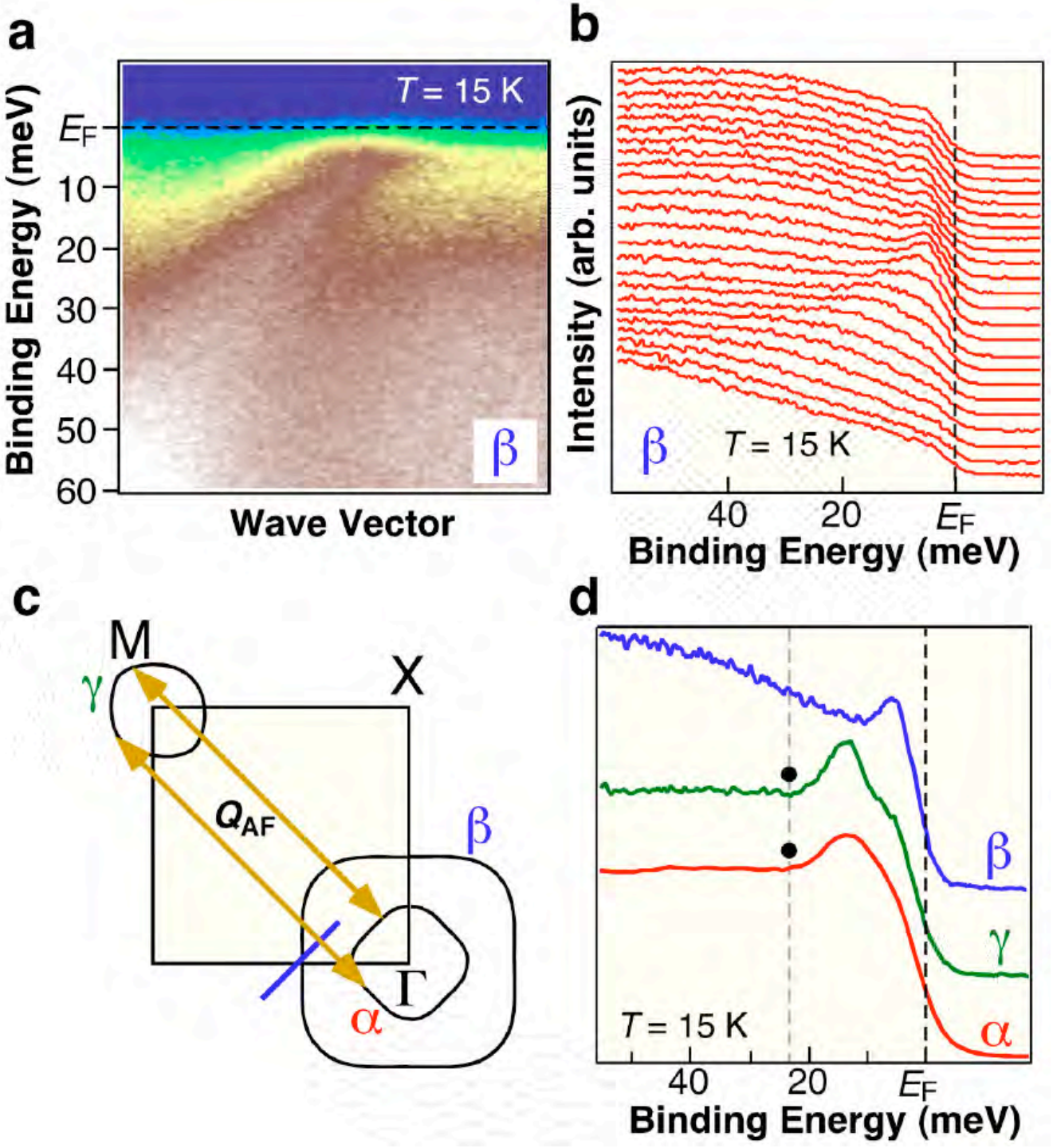


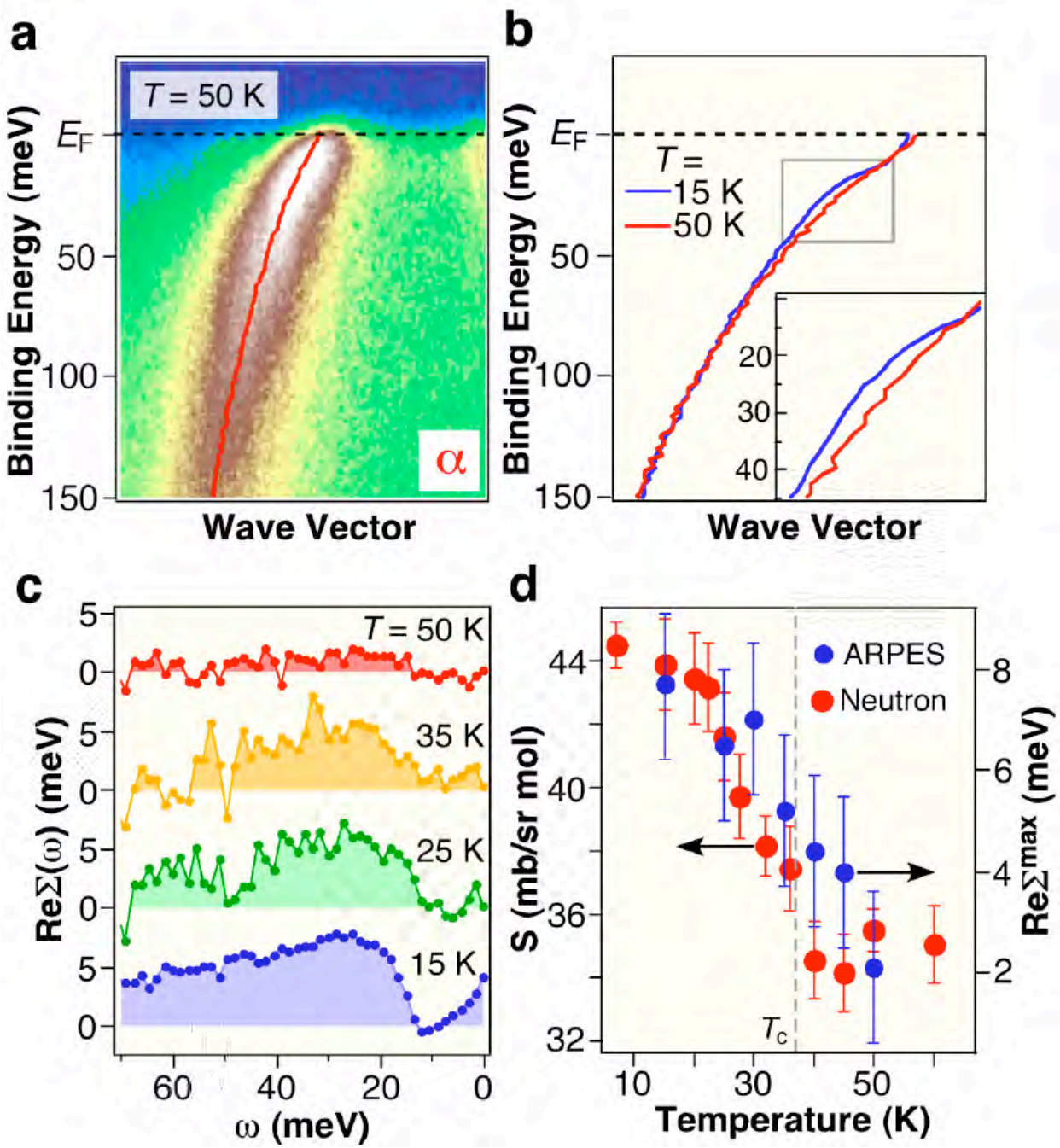
Observation of a dispersion kink in the superconducting state

P. Richard *et al.*, arXiv: 0808.1809, PRL accepted

A low-energy kink observed in the α band

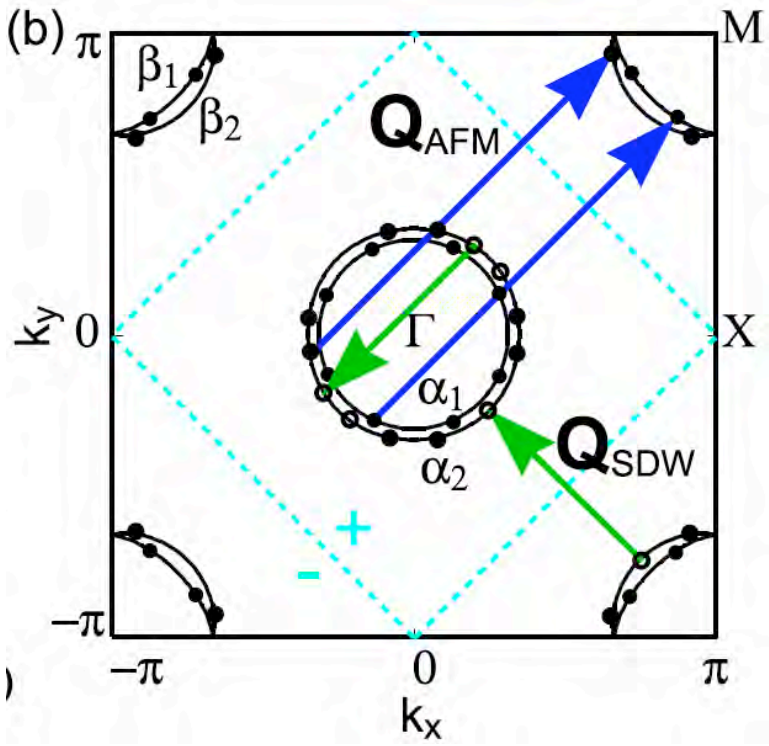


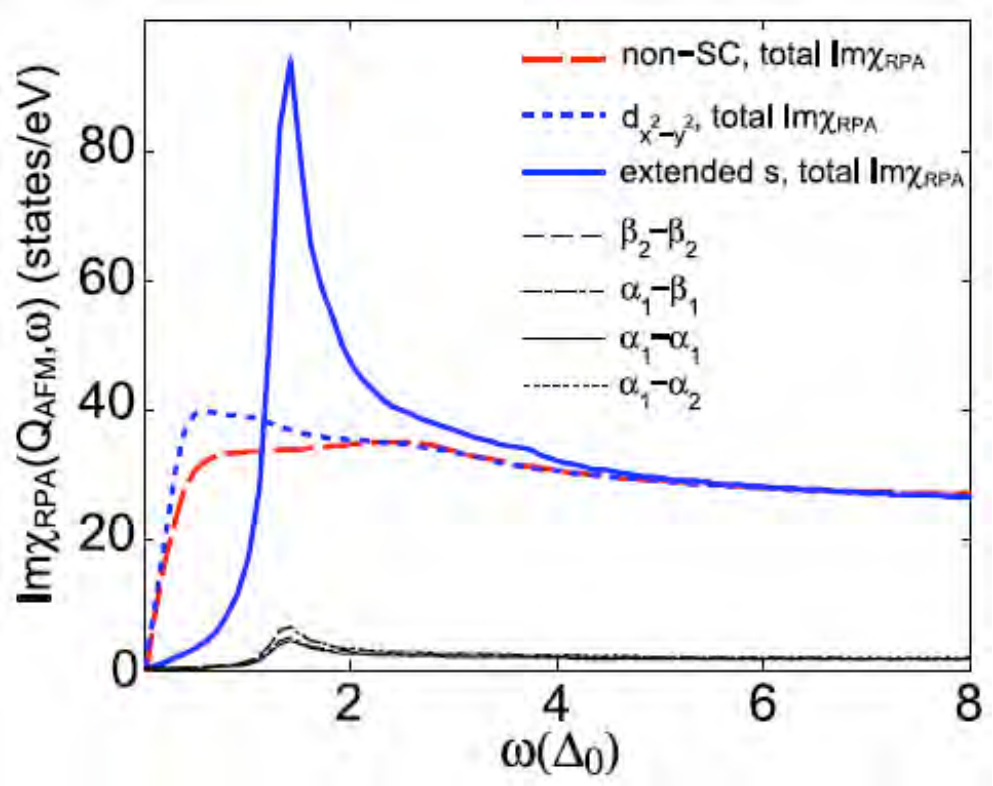

a
T = 15 K
E_F
10
20
30
40
50
60
Binding Energy (meV)
Wave Vector
β
b
Intensity (arb. units)
β
T = 15 K
40
20
E_F
Binding Energy (meV)
c
M
X
γ
Q_AF
β
Γ
α
d
β
γ
α
T = 15 K
40
20
E_F
Binding Energy (meV)



A.D.Christianson et al., arXiv:0807.3932

Consistent with antiphase *s-wave* (or $s^{\pm}$)





M.M. Korshunov and I. Eremin, cond-mat/0804.1793

Conclusions

Inter-pocket (π, π) interactions,
with spin nature,
play an important role in paring

Fermi surface nesting enhances pairing

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