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

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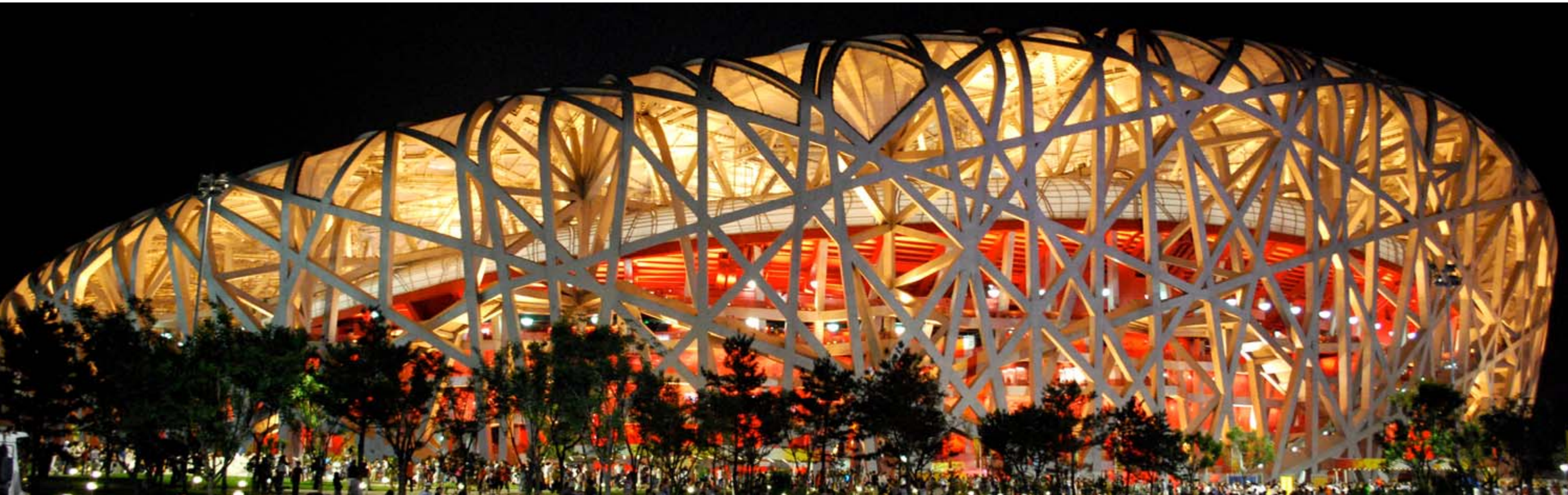

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SNS 2010 Shanghai

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Welcome

Welcome to the 9th International Conference on Spectroscopies in Novel Superconductors (SNS2010), which will be held on May 23-28, 2010, in Shanghai, China.

SNS2010 continues the tradition of previous SNS meetings held at Argonne (1991), Sendai (1992), Santa Fe (1993), Stanford (1995), Cape Cod (1997), Chicago (2001), Sitges (2004), and Sendai (2007). The purpose of SNS2010 is to provide an opportunity for the international scientific community to discuss the recent experimental and theoretical developments in advanced materials and novel electronic properties in connection with superconductivity.

Important Dates

1	Abstract Submission Deadline	Extended to February 28, 2010
2	Early Registration Deadline	January 31, 2010
3	Hotel Reservation Deadline	March 31, 2010
4	Manuscript Submission Deadline	May 24, 2010

Login

ICAM workshop of "Physics of Novel Energy Materials"
Beijing, May 31 – June 3, 2010

Collaborators

ARPES:

Boston College: Yiming Xu, M. Neupane, Z.-H. Pan

Tohoku Univ.: P. Richard, K. Nakayama, T. Kawahara, T. Qian, K. Sugawara, T. Arakane, Y. Sekiba, A. Takayama, S. Souma, T. Sato, T. Takahashi

IOP: Jon Bowen, Y.-B. Huang

UVSOR: K. Terashima

ALS: Alexei Fedorov

Theory:

BC: Z. Wang

IOP: X. Dai, Z. Fang

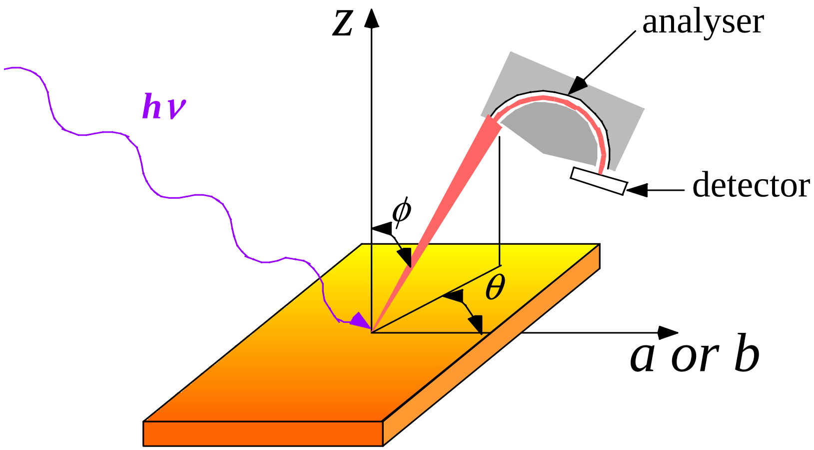
Samples:

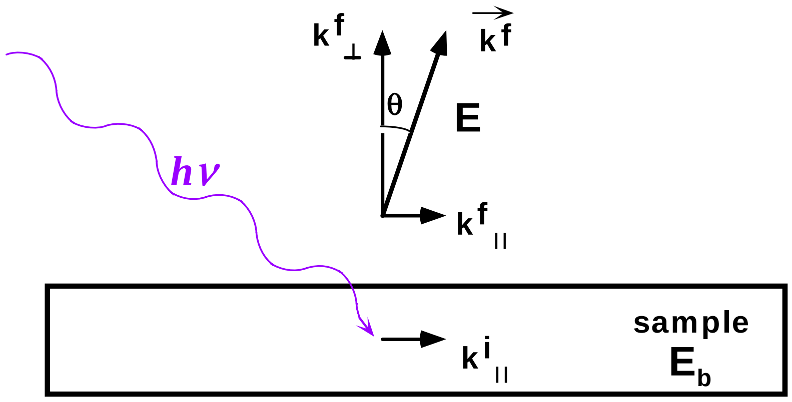
IOP: G.-F. Chen, J.-L. Luo, N.-L. Wang

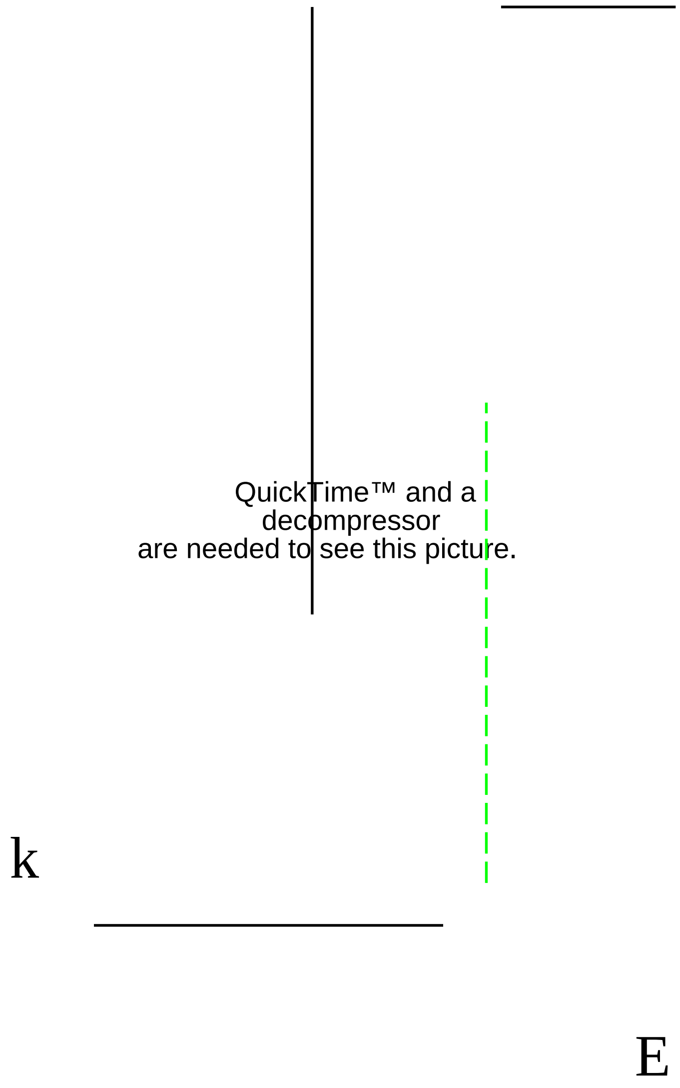
H.-Q. Luo, H.-H. Wen

Zhejiang Univ.: L. J. Li, G. H. Cao, Z.-A. Xu

ARPES maps band structure and Fermi surface







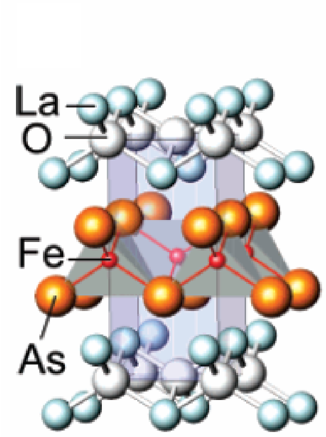
$$E = h\nu - W - E_b$$

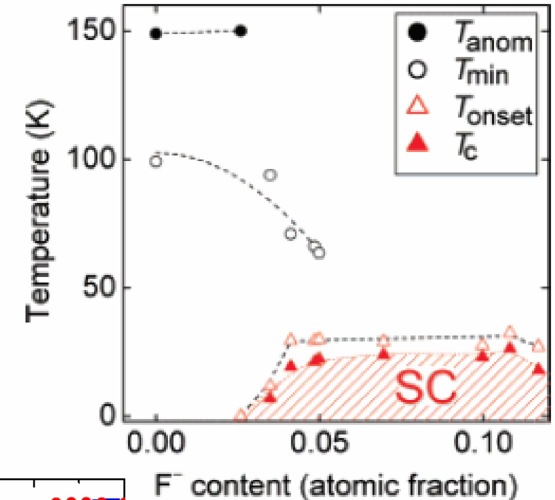
$$k^f_{\parallel} = k^i_{\parallel}$$

$$k^f_{\parallel} = \sqrt{\frac{2mE}{\hbar^2}}\,\sin\theta$$

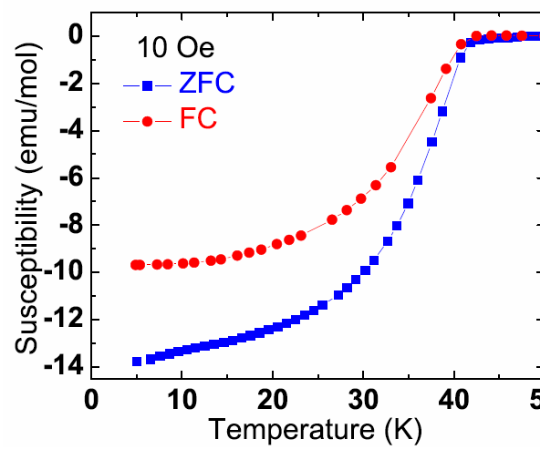
The new iron-based high-T_c (up to 55K) superconductors

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

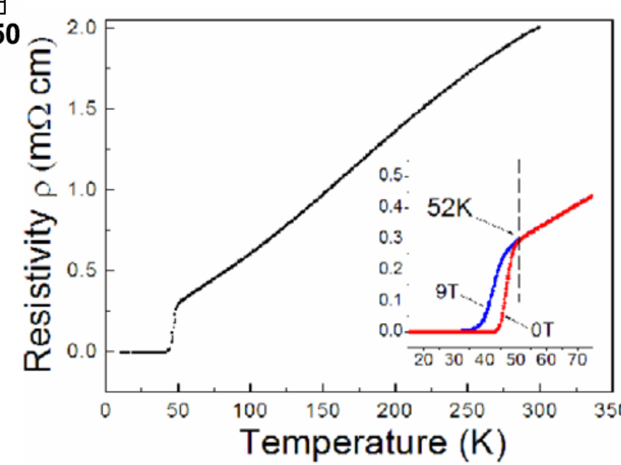




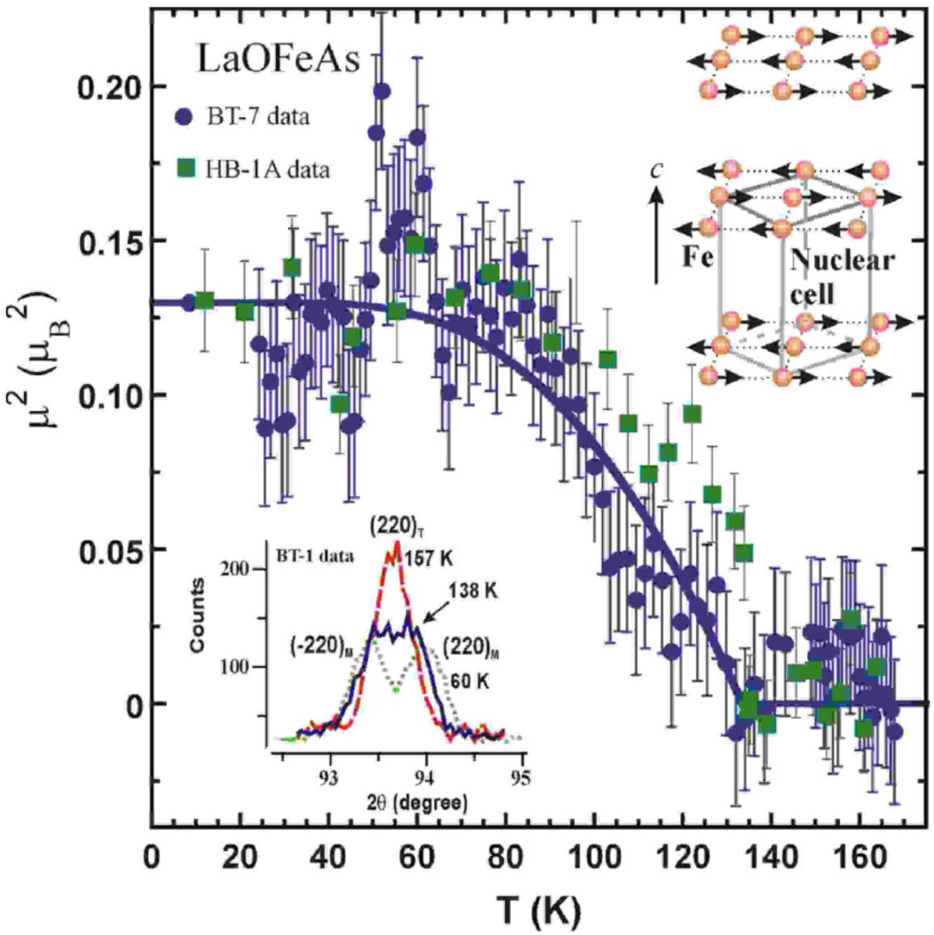
$SmFeAsO_{1-x}F_x$ (T_c = 43K)
X.H. Chen, USTC, China
$CeFeAsO_{1-x}F_x$ (T_c = 41K)
N.L. Wang, IOP, China
March 25-26, 2008



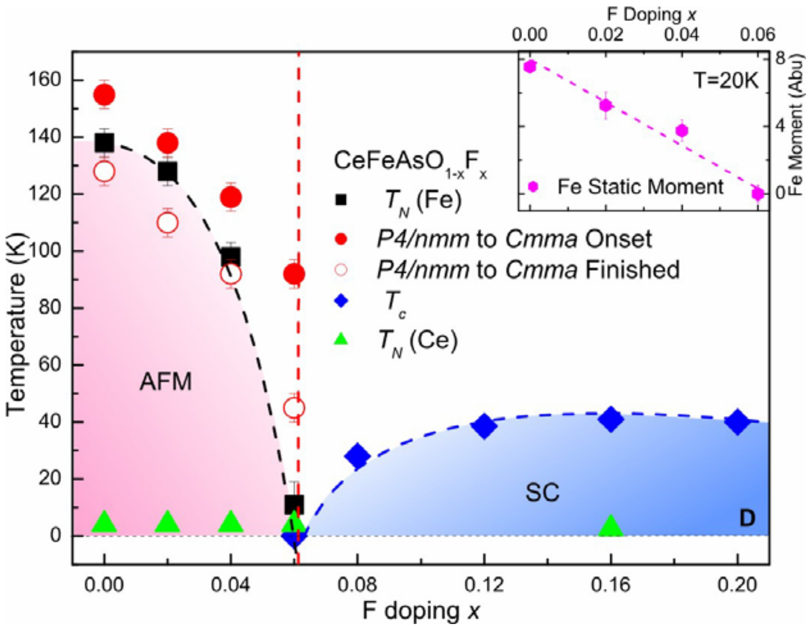
$PrFeAsO_{1-x}F_x$ (T_c = 52K)
Z.X. Zhao, IOP, China
March 28, 2008

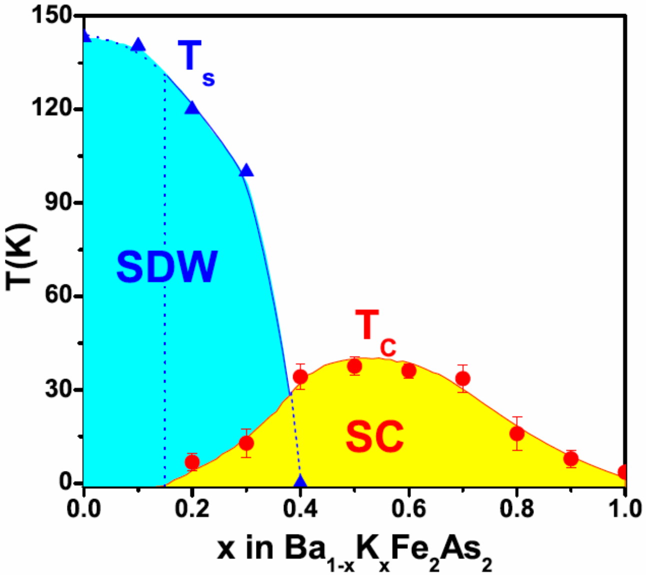


Neutron observation of stripe type SDW



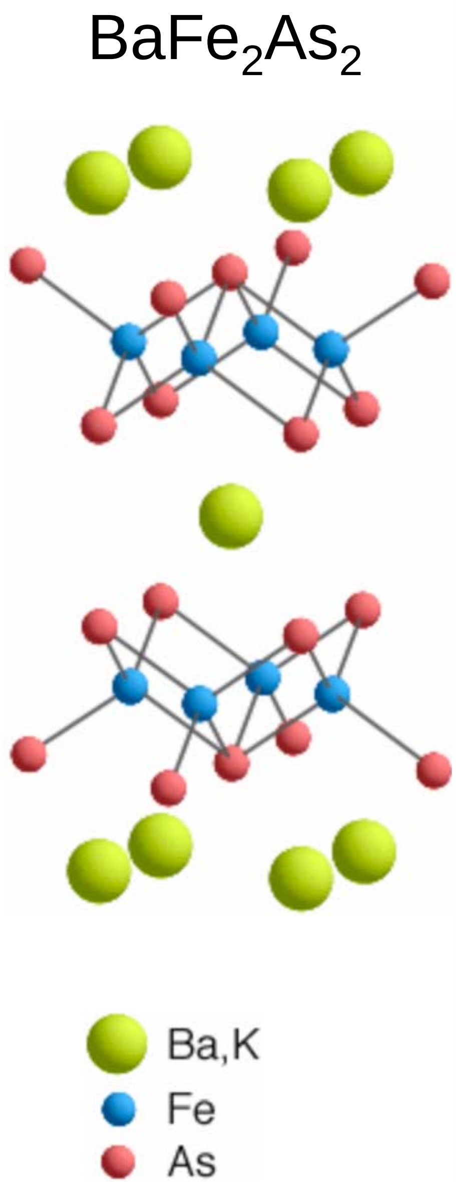
P. C. Dai, Nature 2008

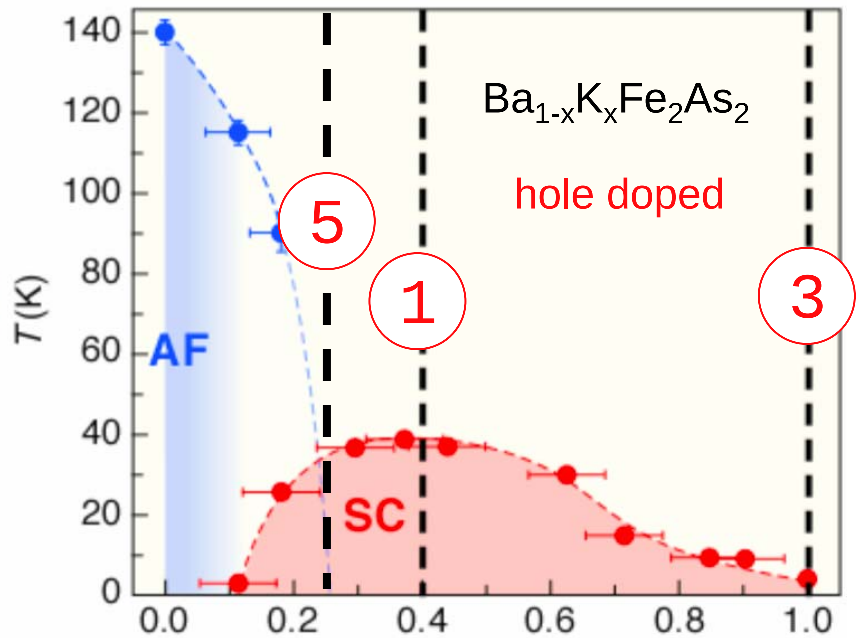


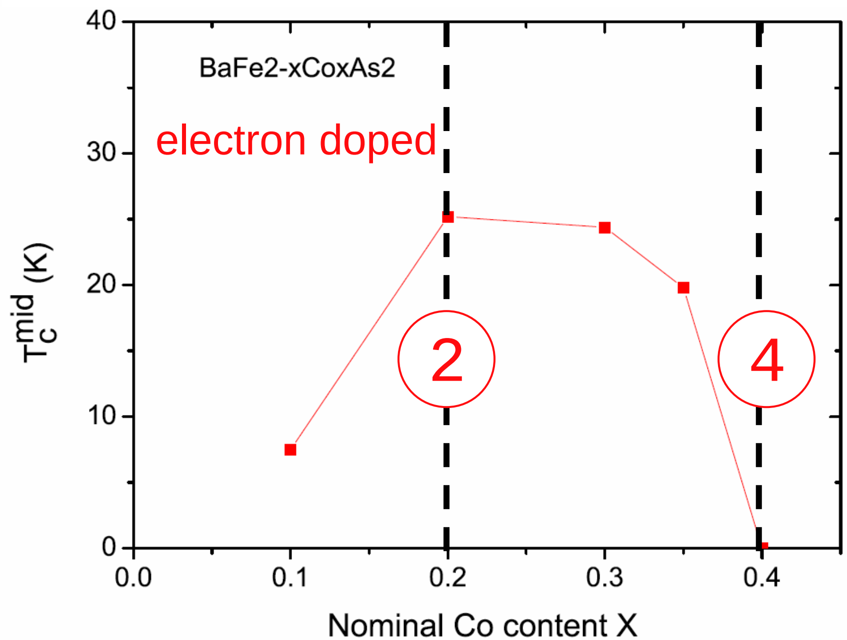


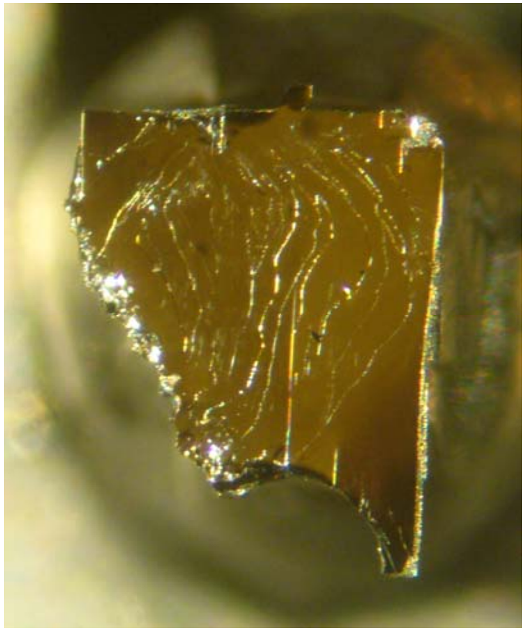
W. Bao, arXiv:0807.3950

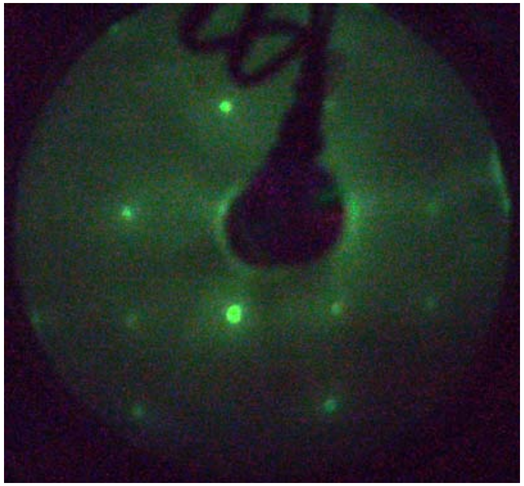
ARPES studies of 5 kinds of “122” compounds



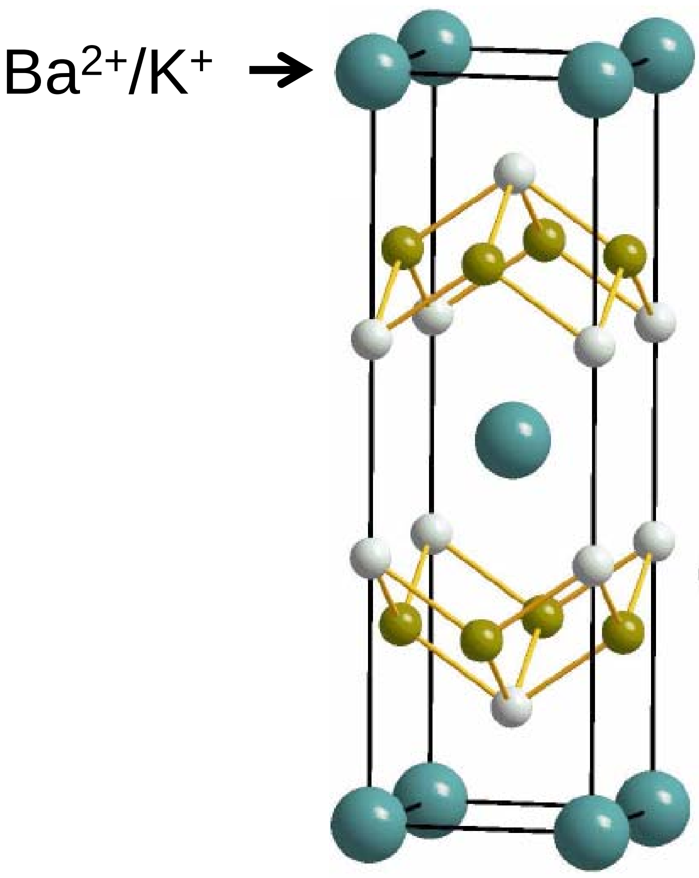






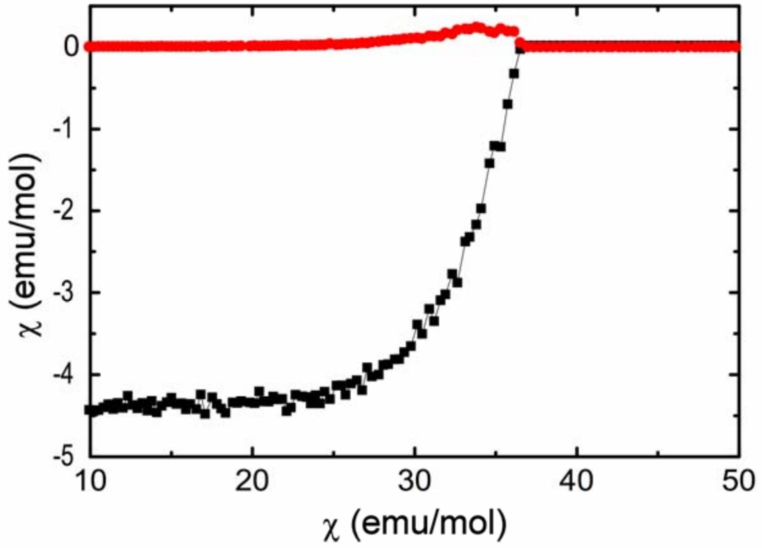


1. Optimally hole doped samples

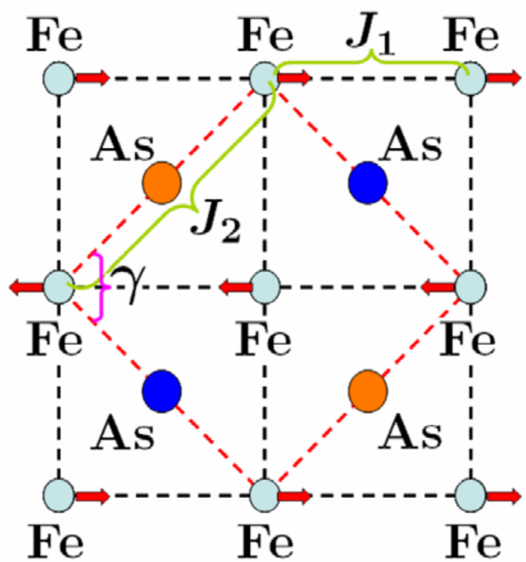


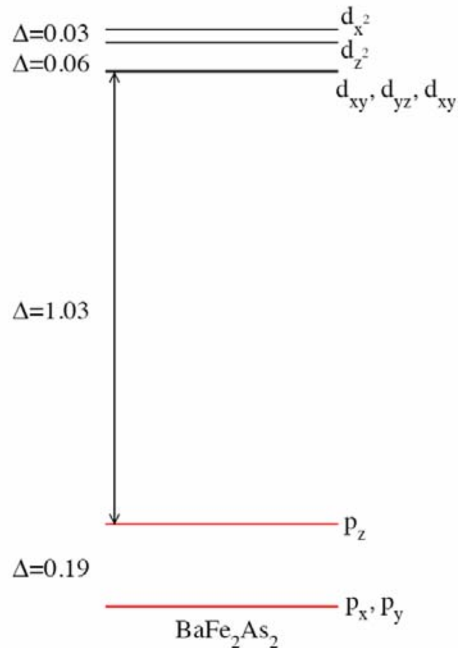
$Ba_{0.6}K_{0.4}Fe_2As_2$

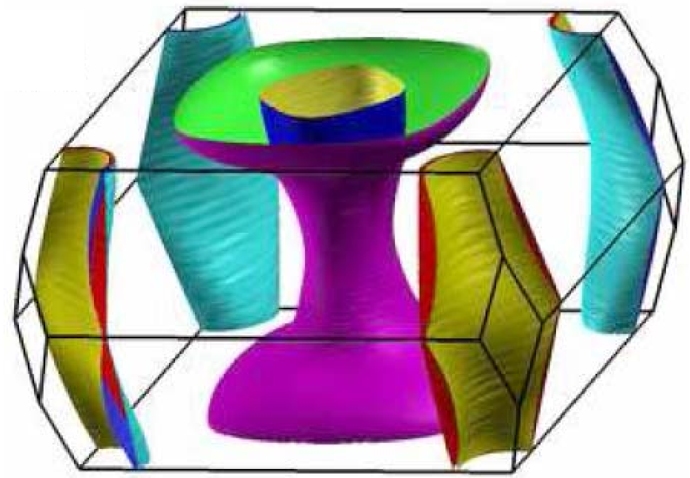
T_c = 37 K

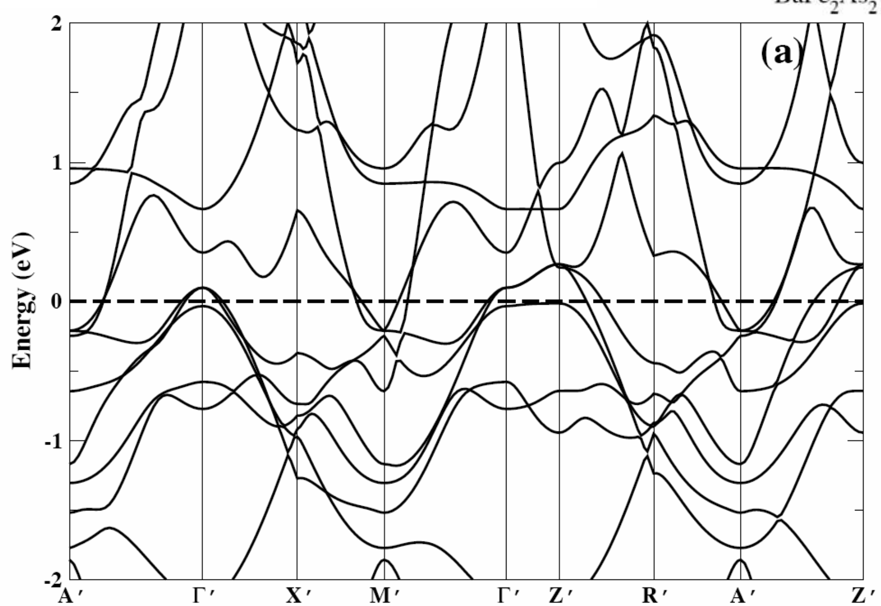


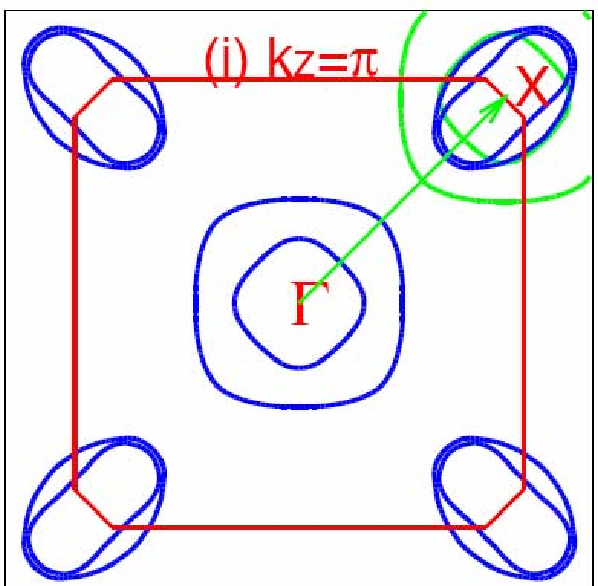
Calculated band structure and Fermi surface



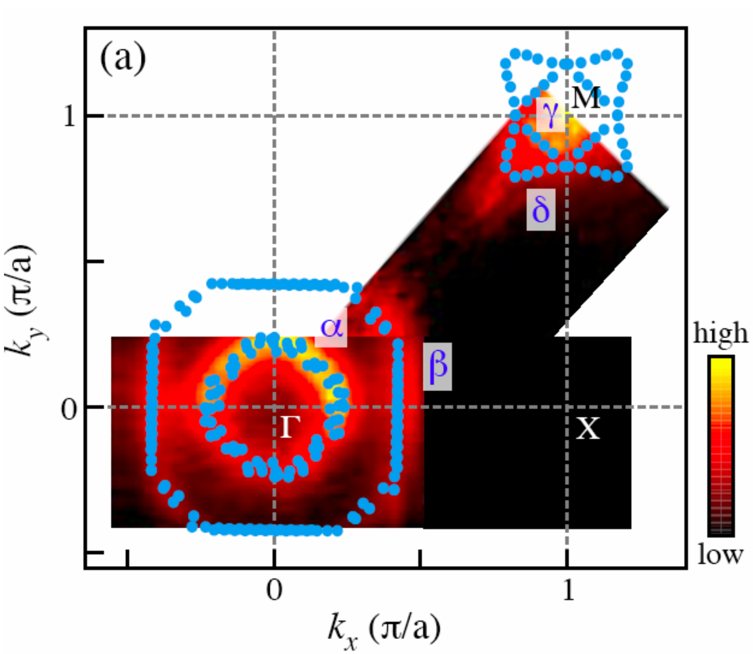


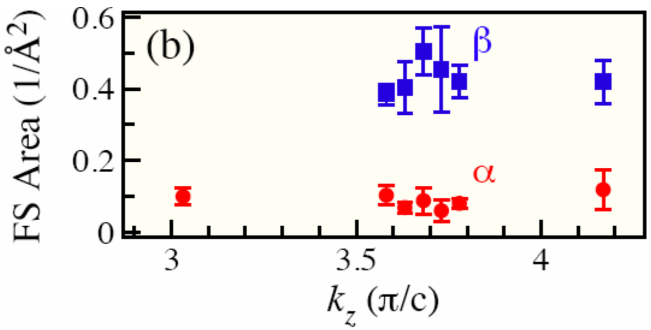






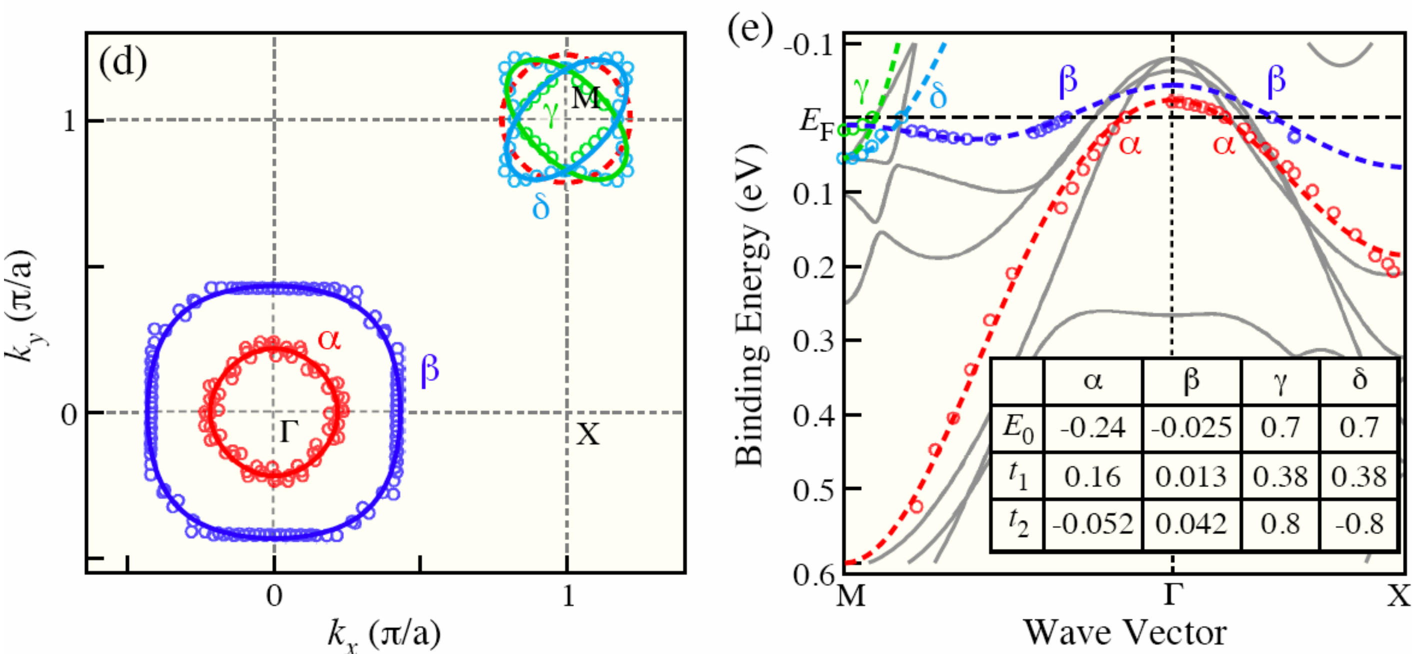
Band structure and Fermi surface





(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

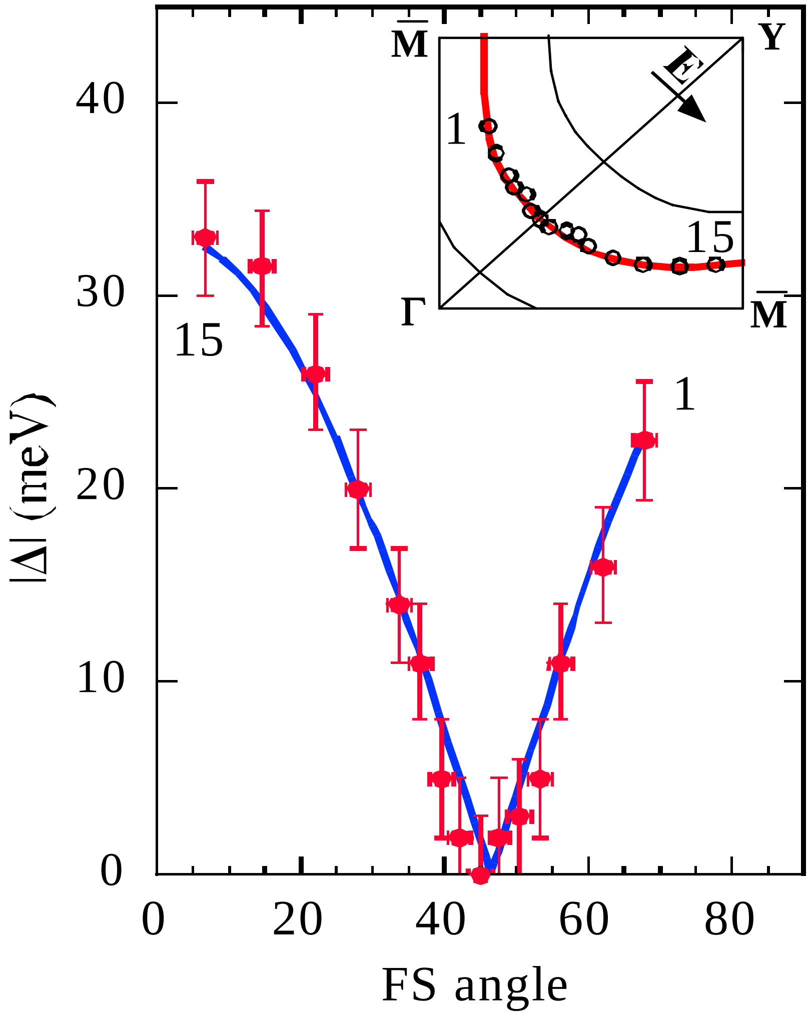


	α	β	γ	δ
E_0	-0.24	-0.025	0.7	0.7
t_1	0.16	0.013	0.38	0.38
t_2	-0.052	0.042	0.8	-0.8

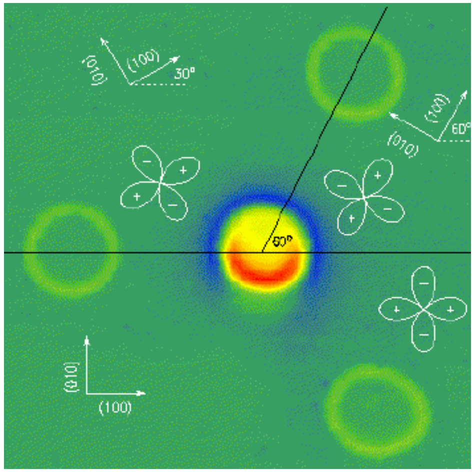
H. Ding *et al*.
arXiv: 0812.0534

SC gap symmetry is crucial in understanding the SC mechanism

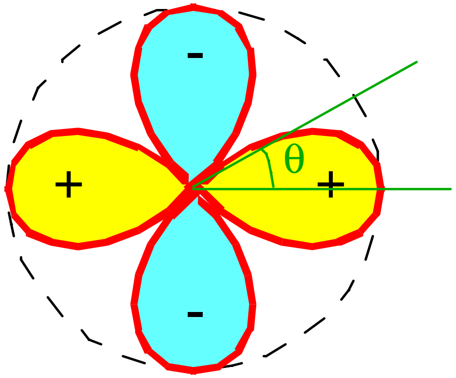
d-wave in cuprates



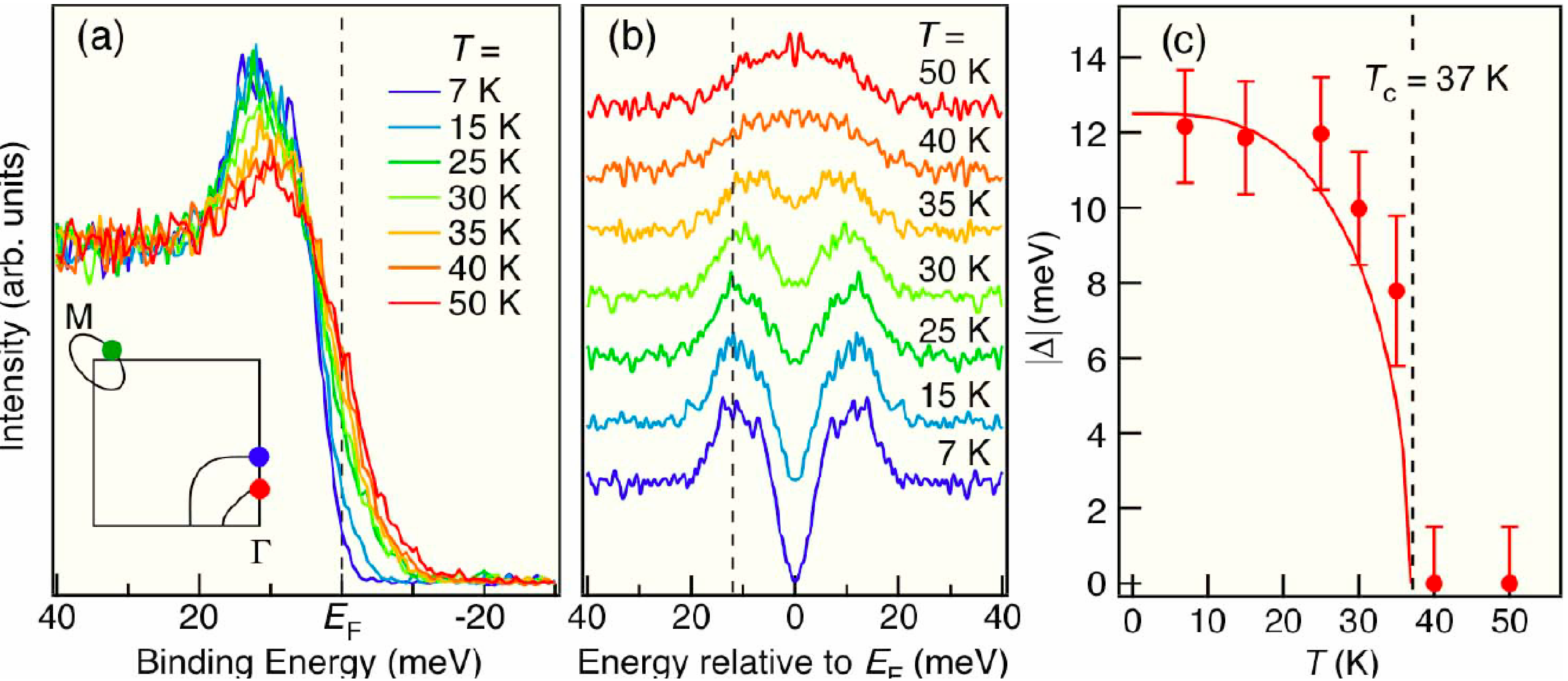
Half-Integer Flux Quantum Effect



$d_{x^2-y^2}$

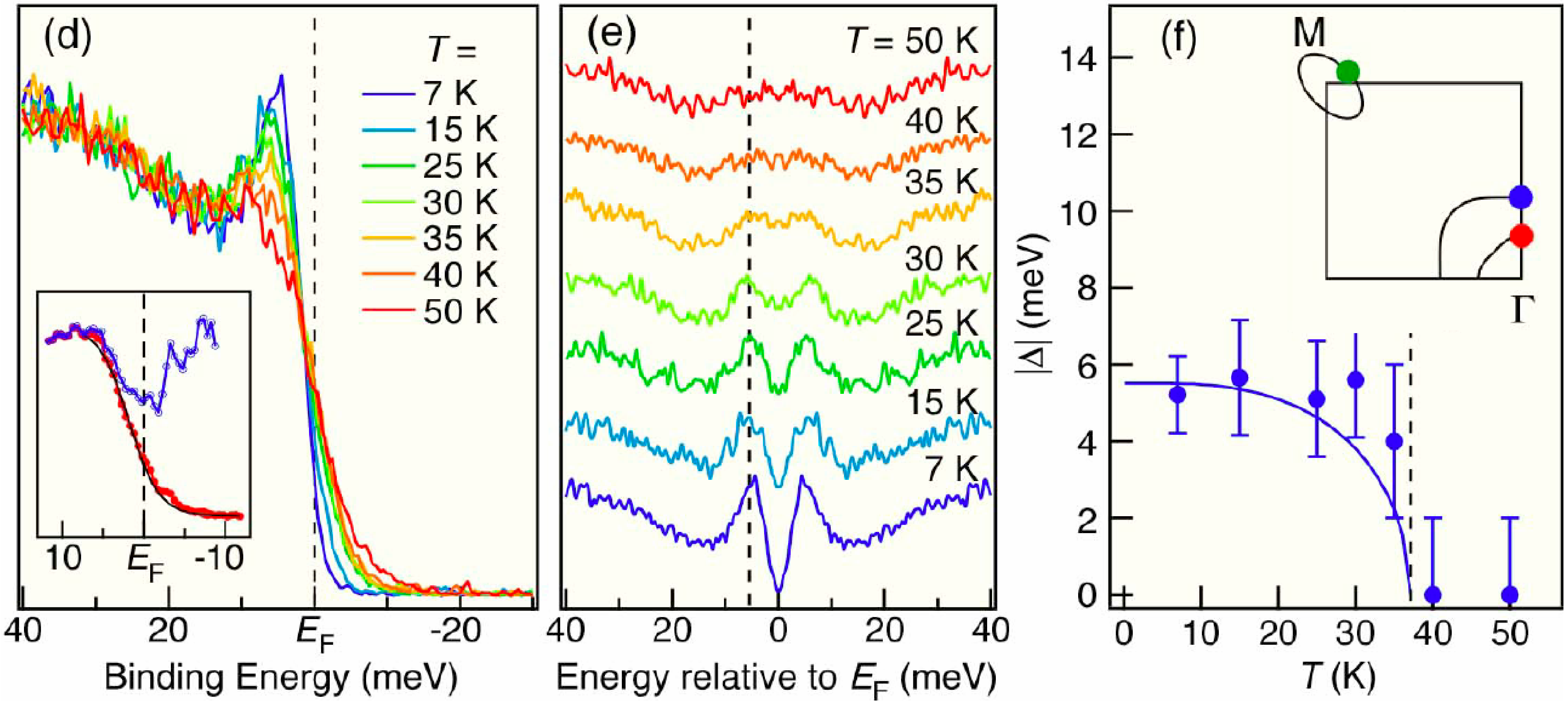


T-dependence of the SC gap at the α FS



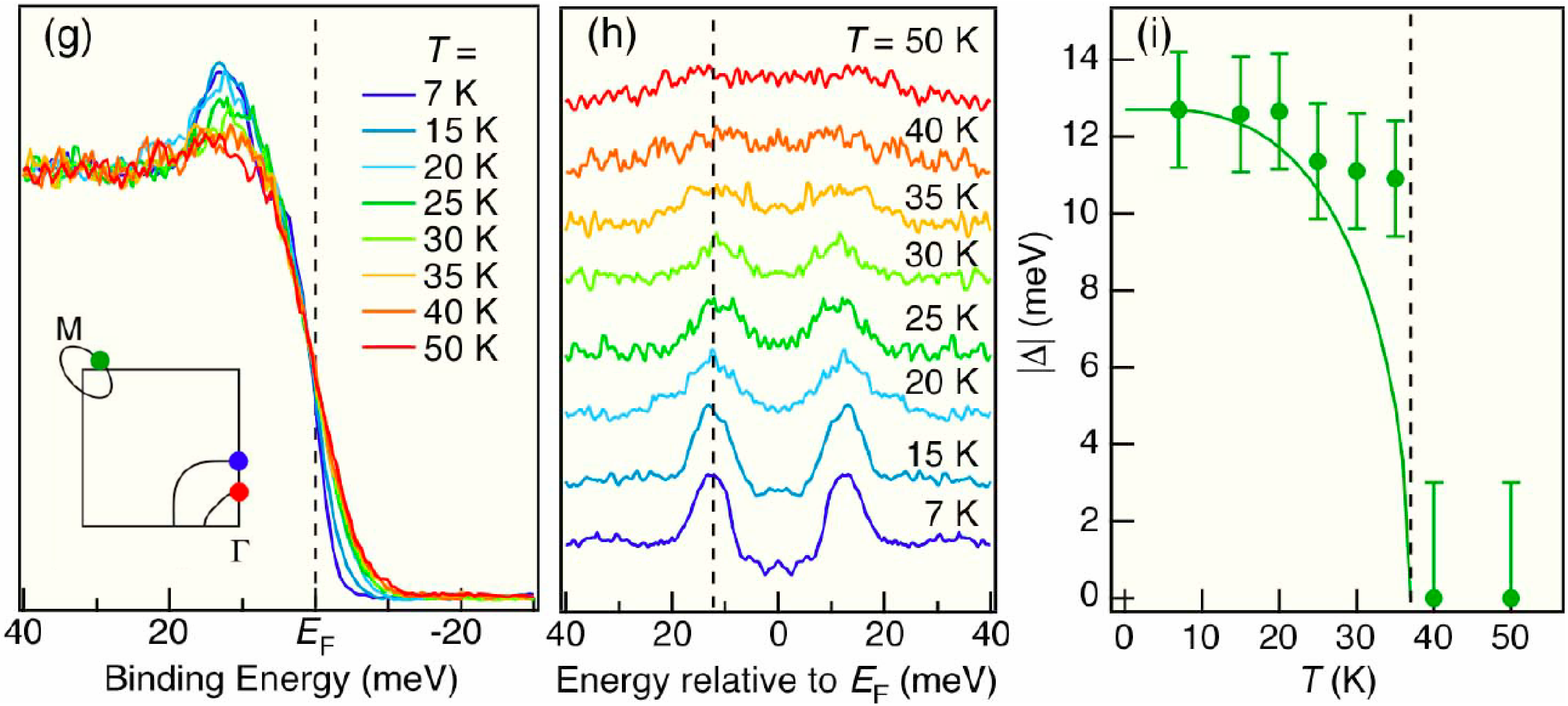
$2\Delta/T_c \sim 7$

T-dependence of the SC gap at the β FS



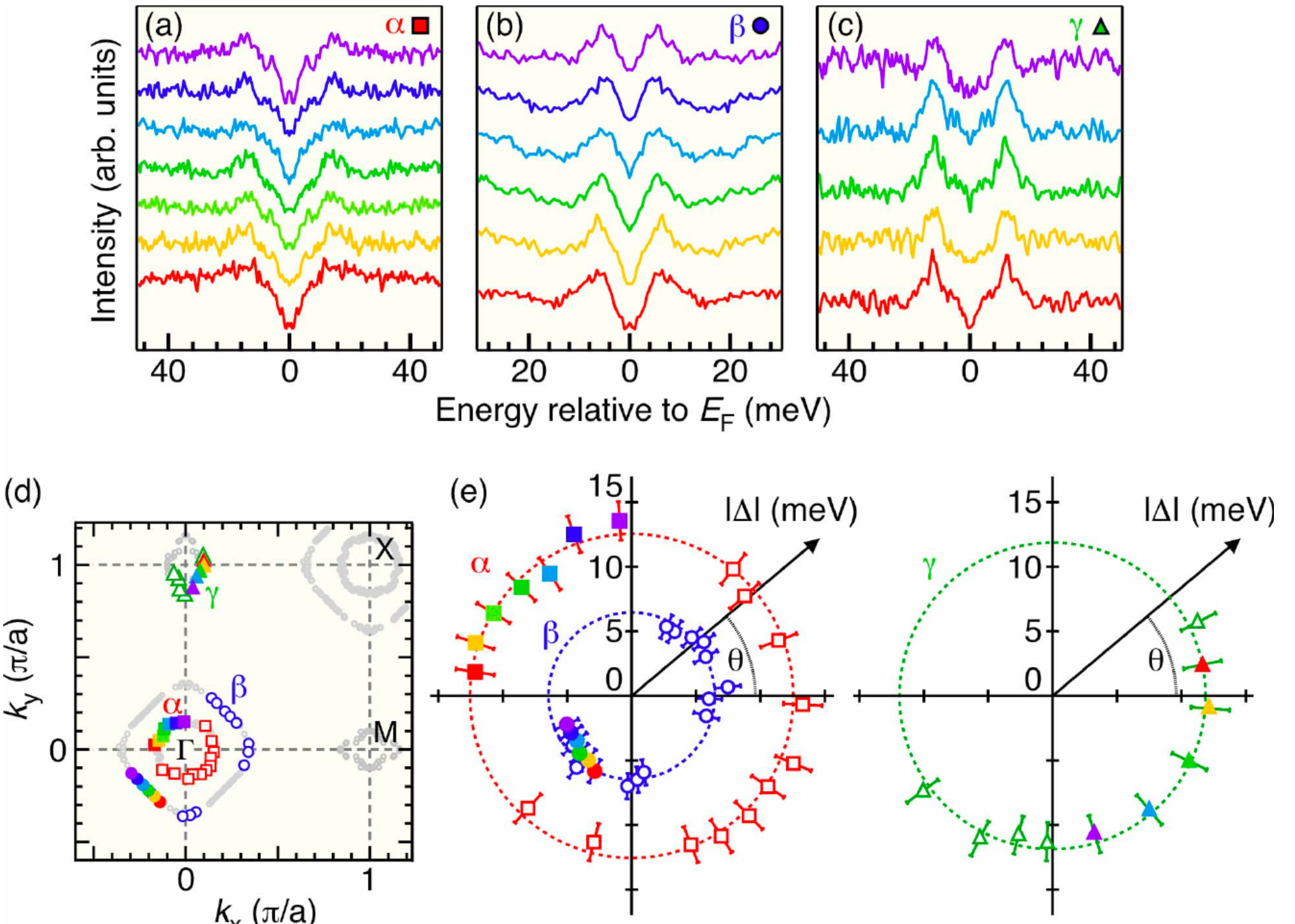
$2\Delta/T_c \sim 3.6$

T-dependence of the SC gap at the γ FS

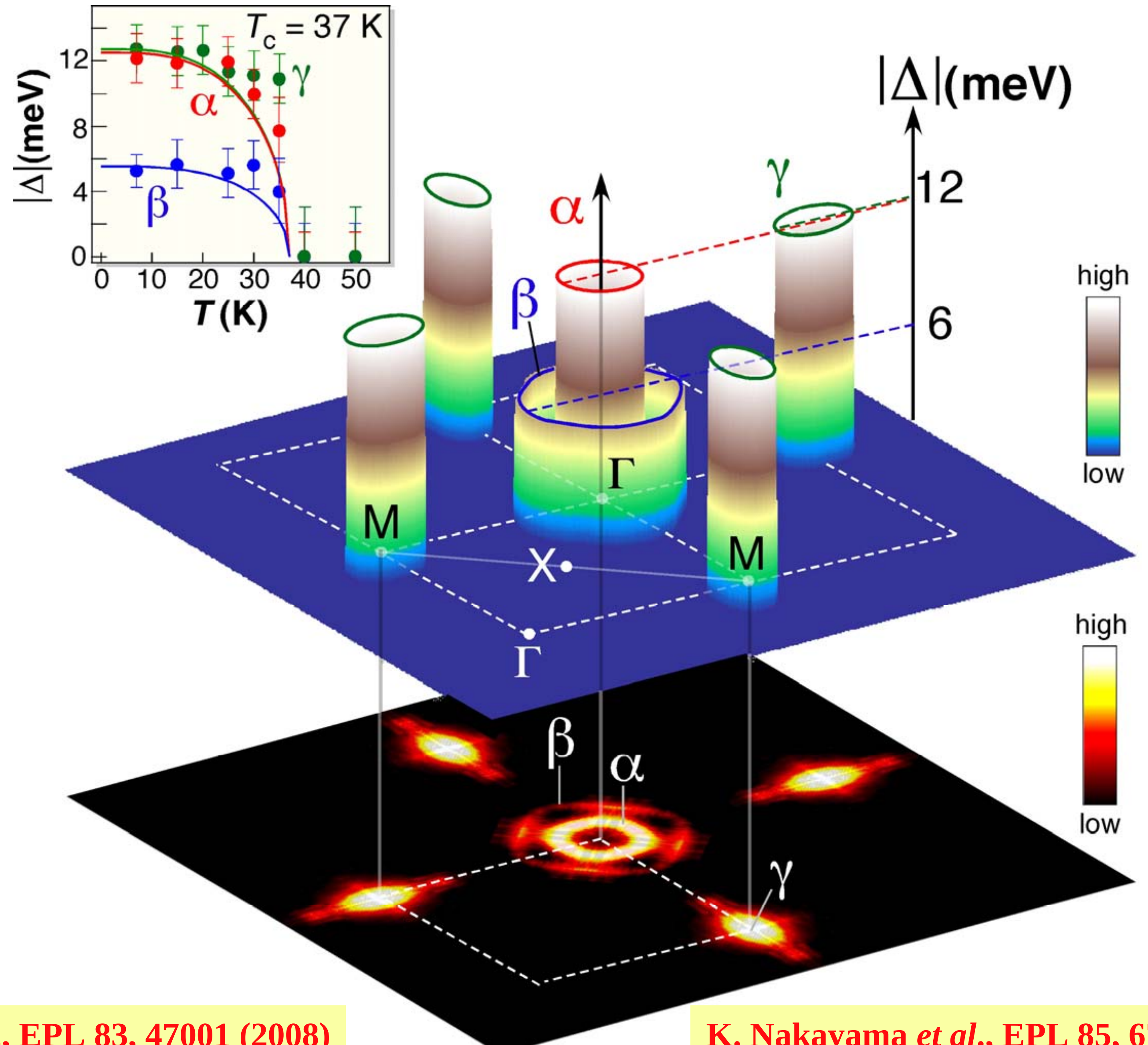


$2\Delta/T_c \sim 7$

Momentum dependence of the superconducting gap



Fermi surface dependent but isotropic pairing

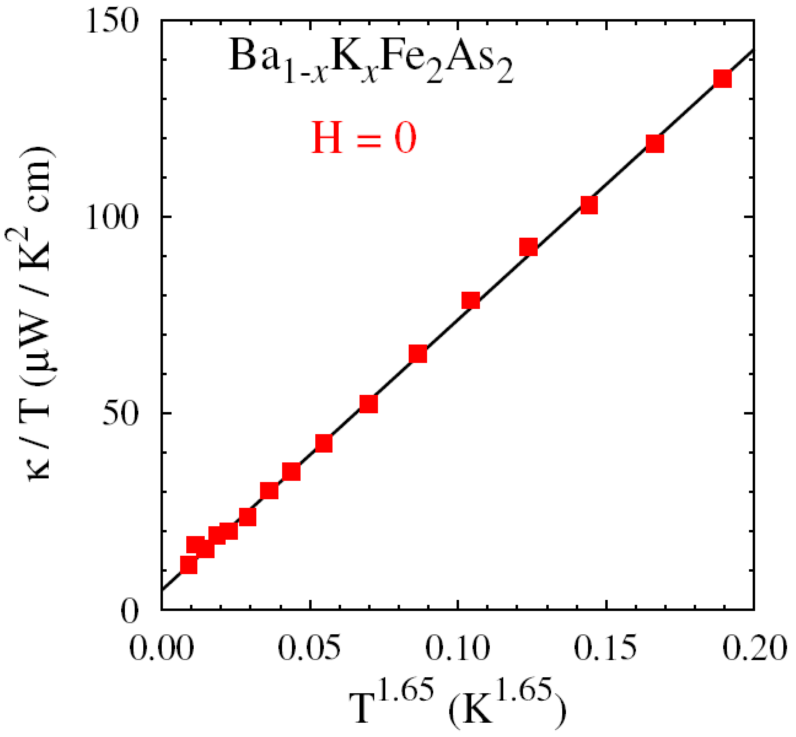


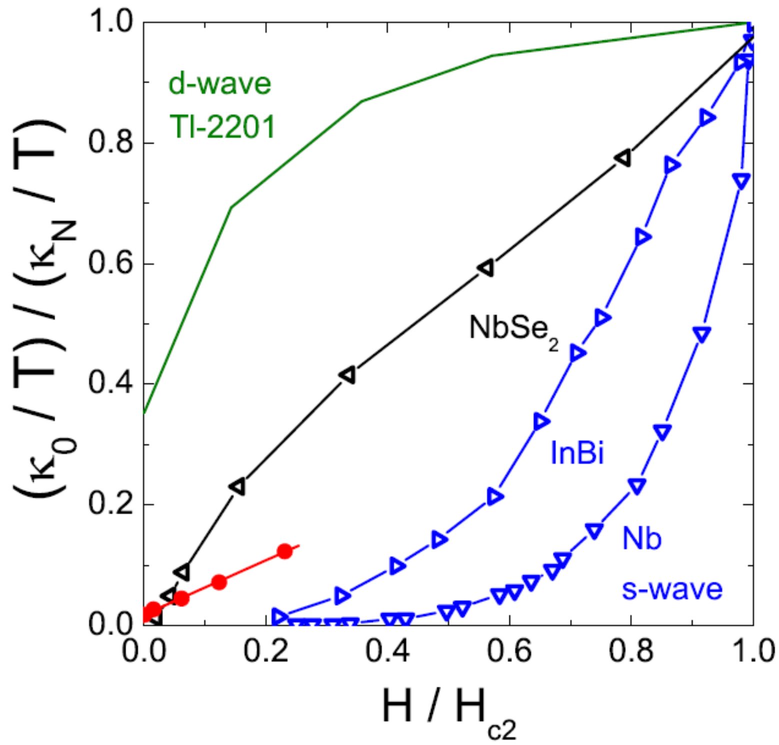
H. Ding *et al.*, EPL 83, 47001 (2008)

K. Nakayama *et al.*, EPL 85, 67002 (2009)

Nodeless gap confirmed by thermal conductivity

$_0$/T **hole-doped $Ba_{1-x}K_xFe_2As_2$ (Tc ~ 30 K)**



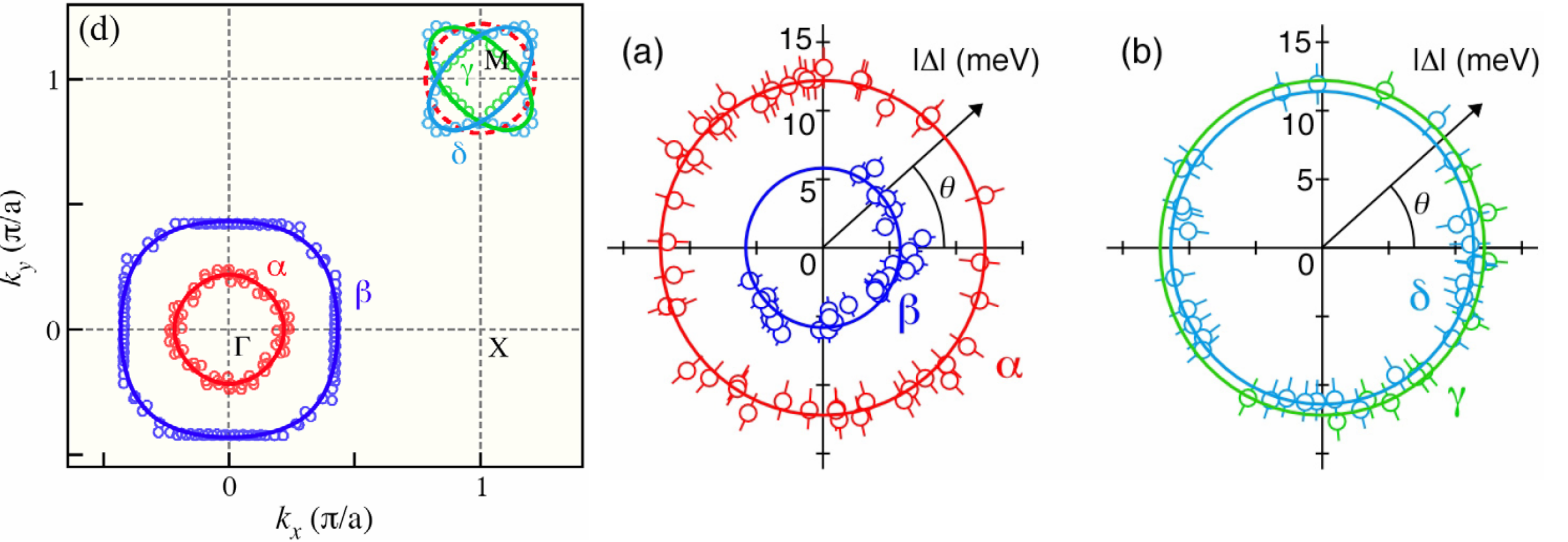


Nodeless gap

k-dependent gap

X. G. Luo *et al.*, PRB **80**, 140503(R) (2009)

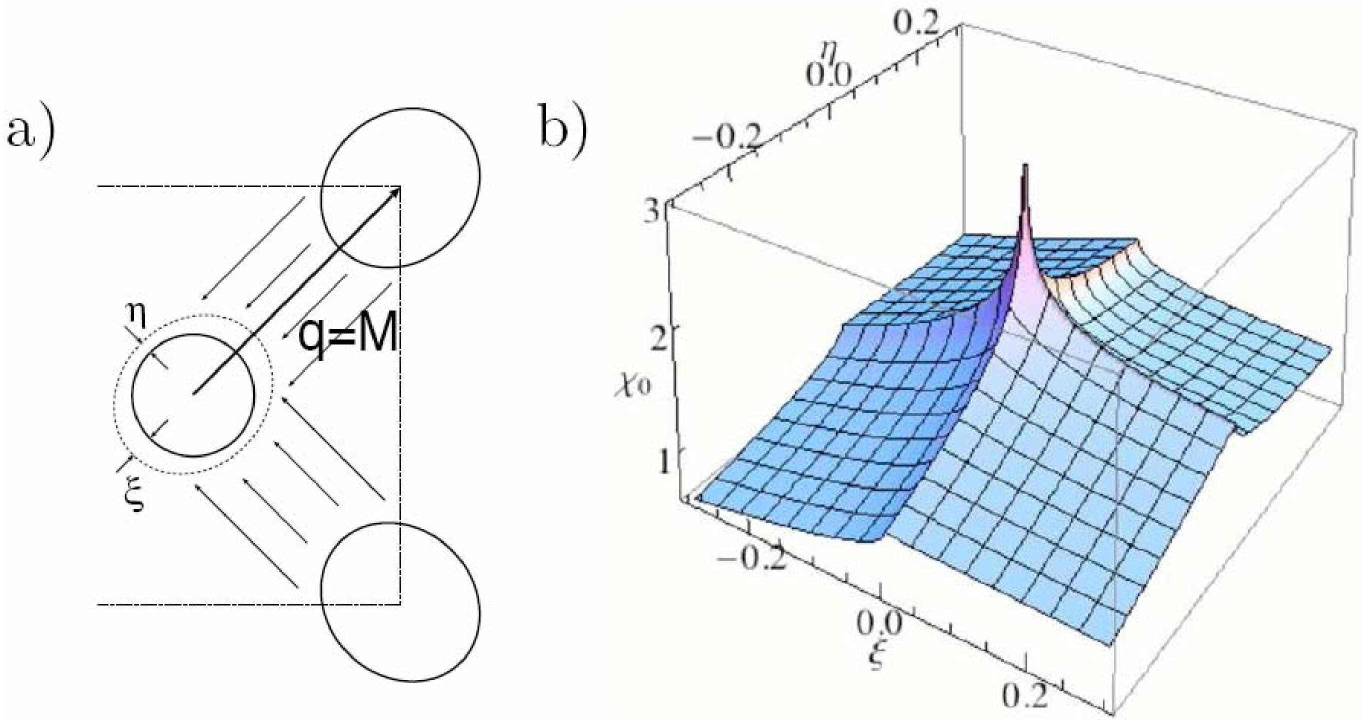
In optimally hole doped samples, quasi FS nesting between the inner (α) hole pocket and the electron pockets



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

Quasi Fermi surface nesting



V. Cvetkovic and Z. Tesanovic, EPL **85**,37002 (2009)

Perfect FS nesting

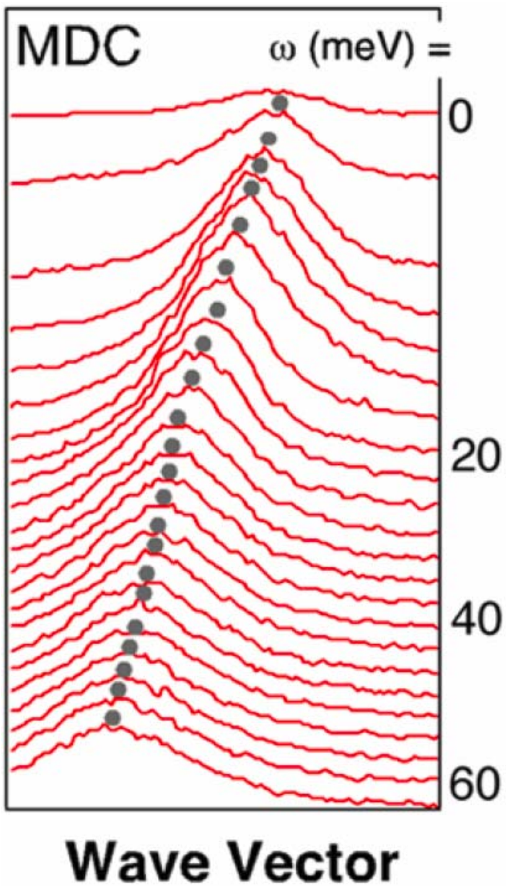
$$\chi_0'(\mathbf{q}, \omega = 0) = 2\frac{m_e}{2\pi} \log \frac{\Lambda}{|\mathbf{q} - \mathbf{M}|}$$

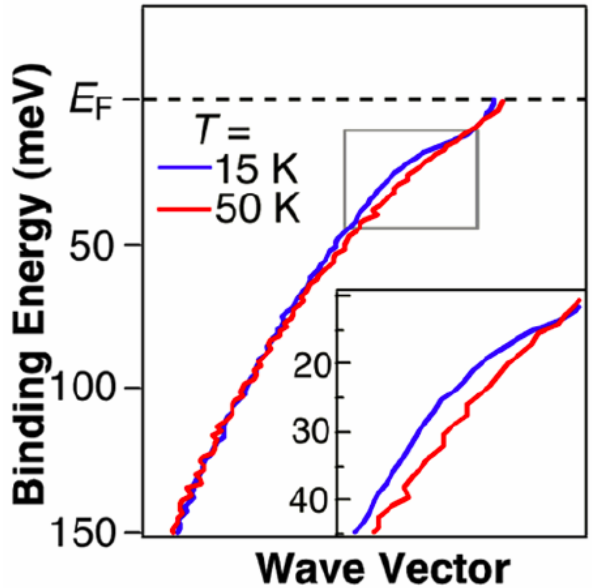
Quasi FS nesting

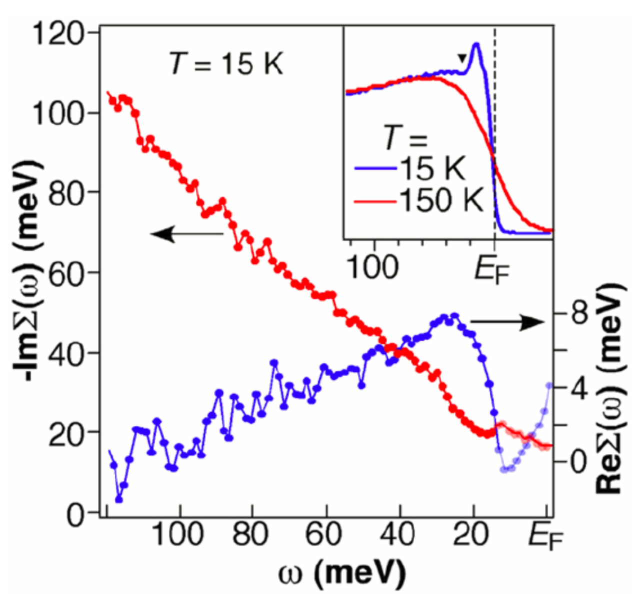
$$\chi_0'(\mathbf{q} = \mathbf{M}, 0) = \frac{4m_e}{2\pi} \frac{(1+\xi)^2}{\Xi} \log \left[\frac{\Lambda}{k_F|\xi|} \sqrt{\frac{2\Xi}{(2+\xi)^2}} \right]$$

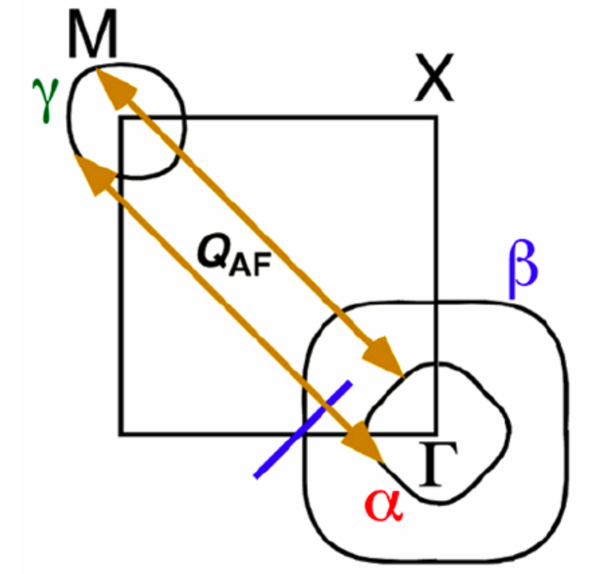
Or dynamic FS nesting, enhances $\chi_0'(q, \omega \neq 0)$

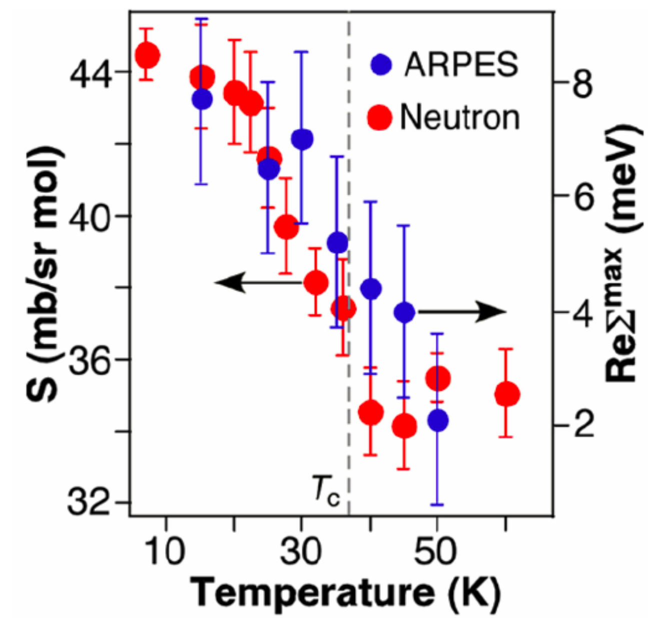
A FS-dependent kink observed in SC state









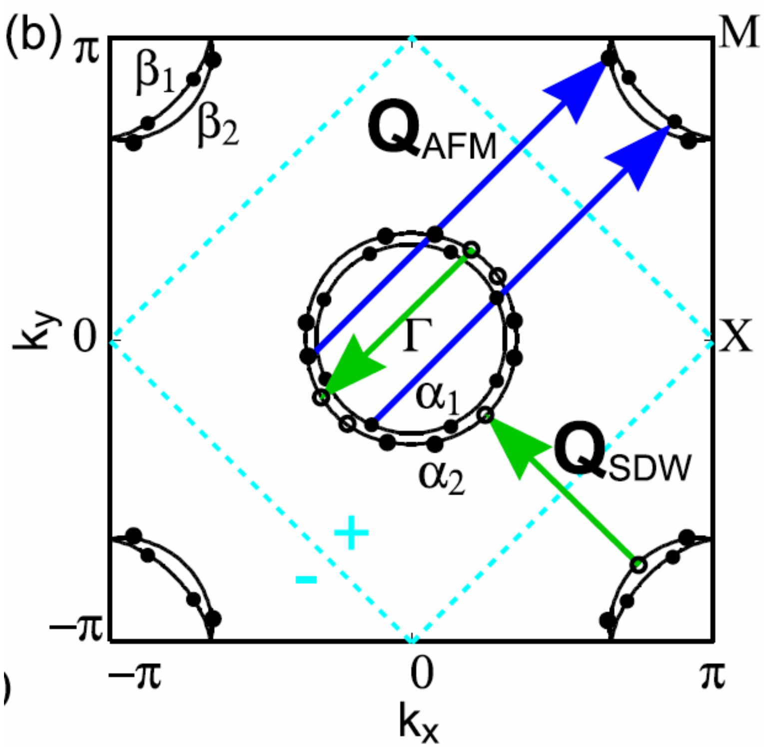


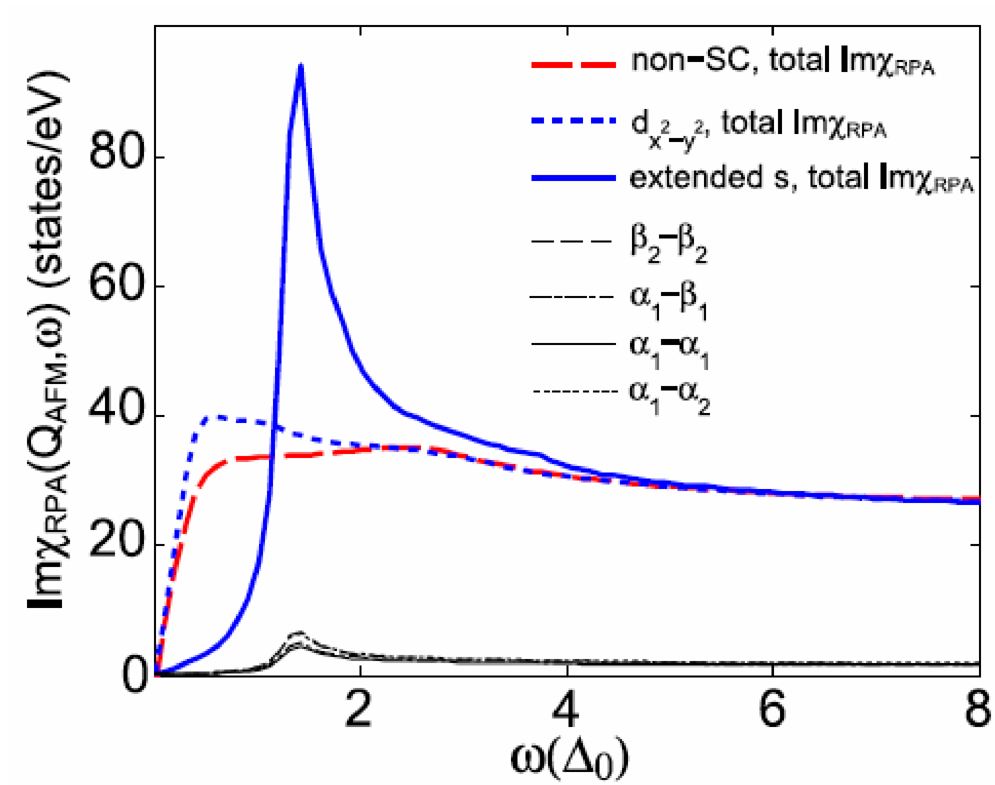
P. Richard *et al.*, PRL 102, 047003 (2009)

Ω ~ 13 meV, similar to neutron resonance mode ~ 14 meV

A.D.Christianson et al., Nature **456**, 930 (2008)

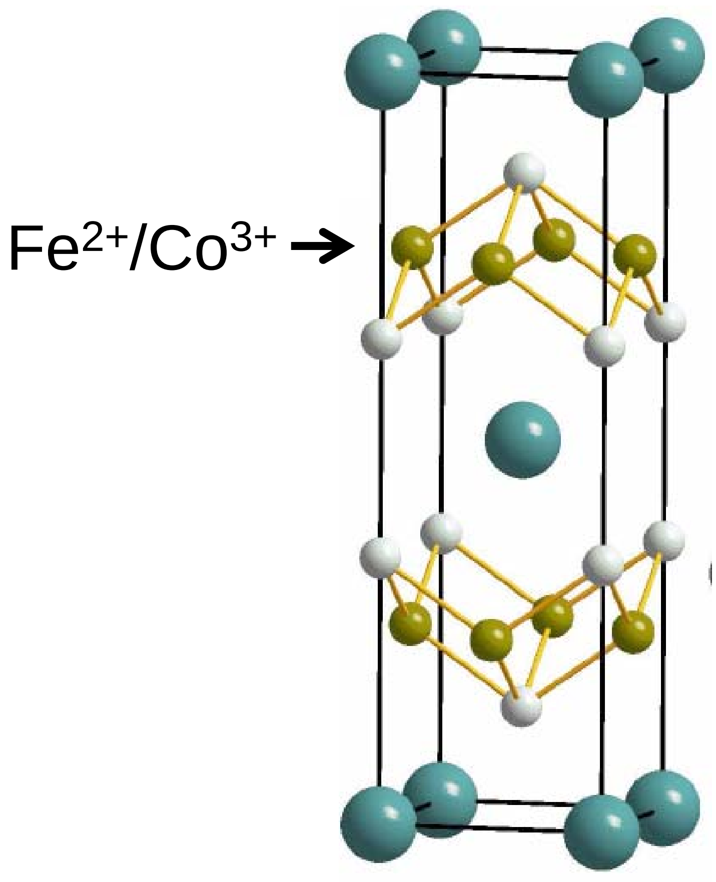
Consistent with extended *s ± pairing model*



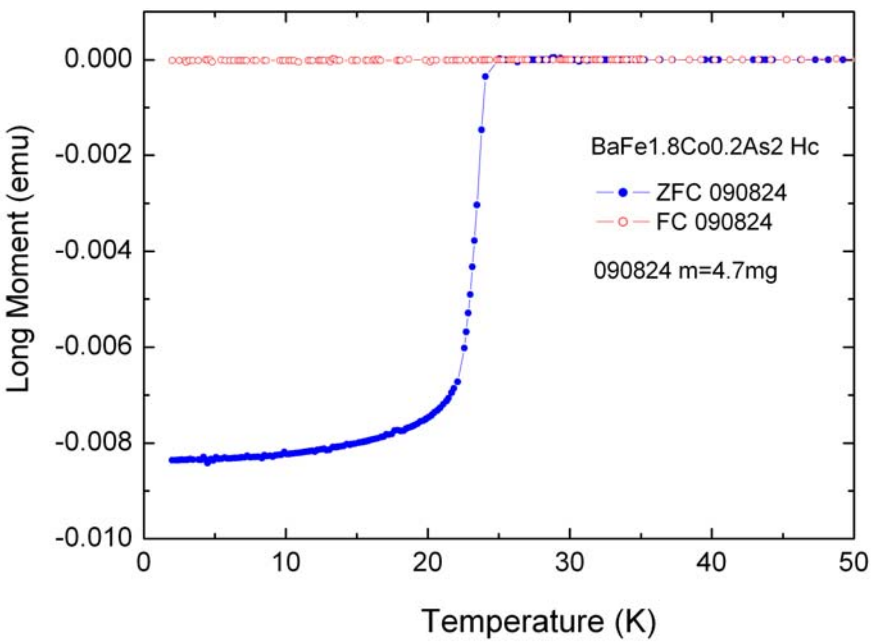


M.M. Korshunov and I. Eremin, Phys. Rev. B 78, 140509 (R) (2008)

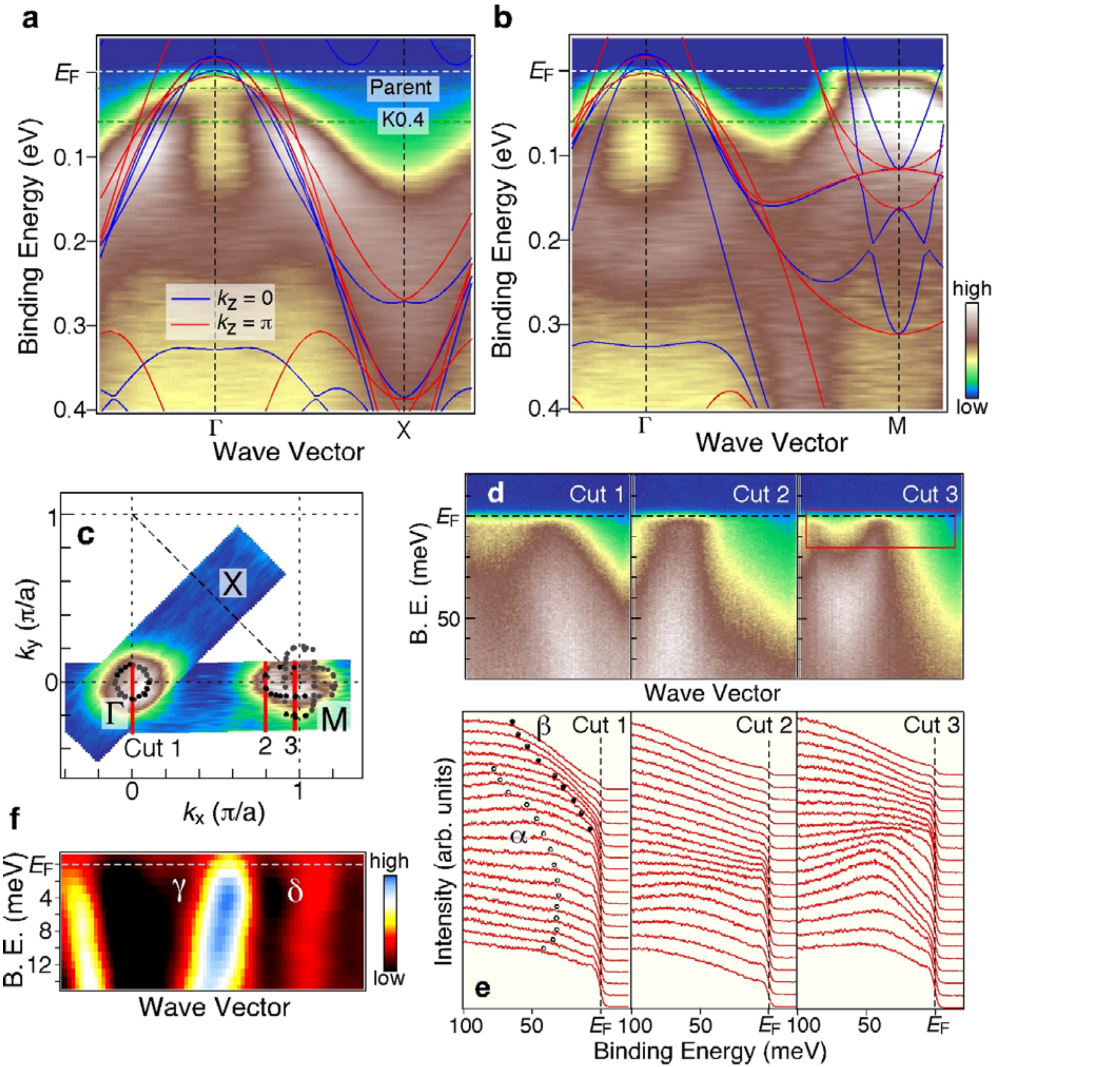
2. Optimally electron doped samples



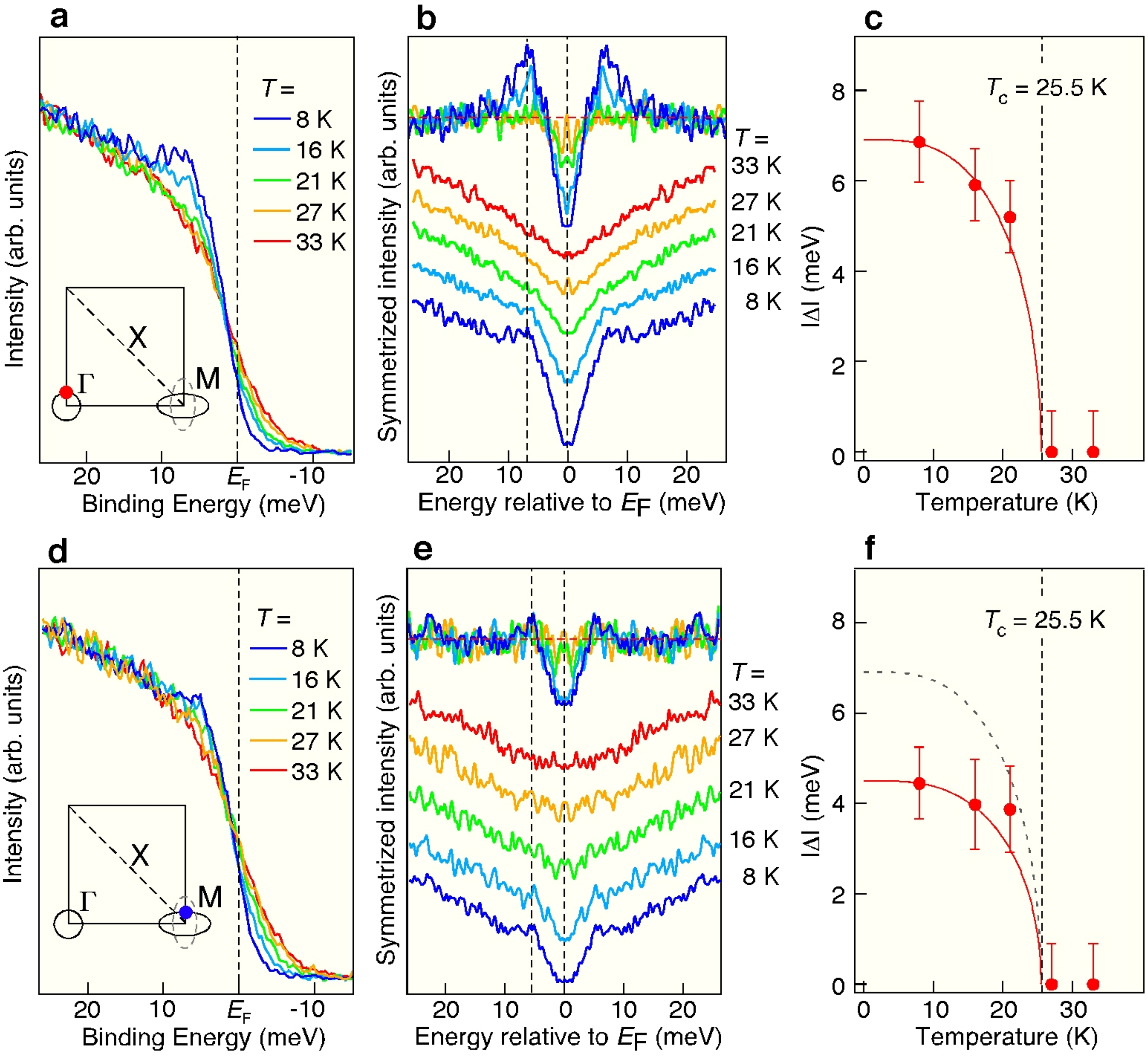
$BaFe_{1.85}Co_{0.15}As_2$ (T_c = 25.5 K)
Nominal Co = 0.2



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



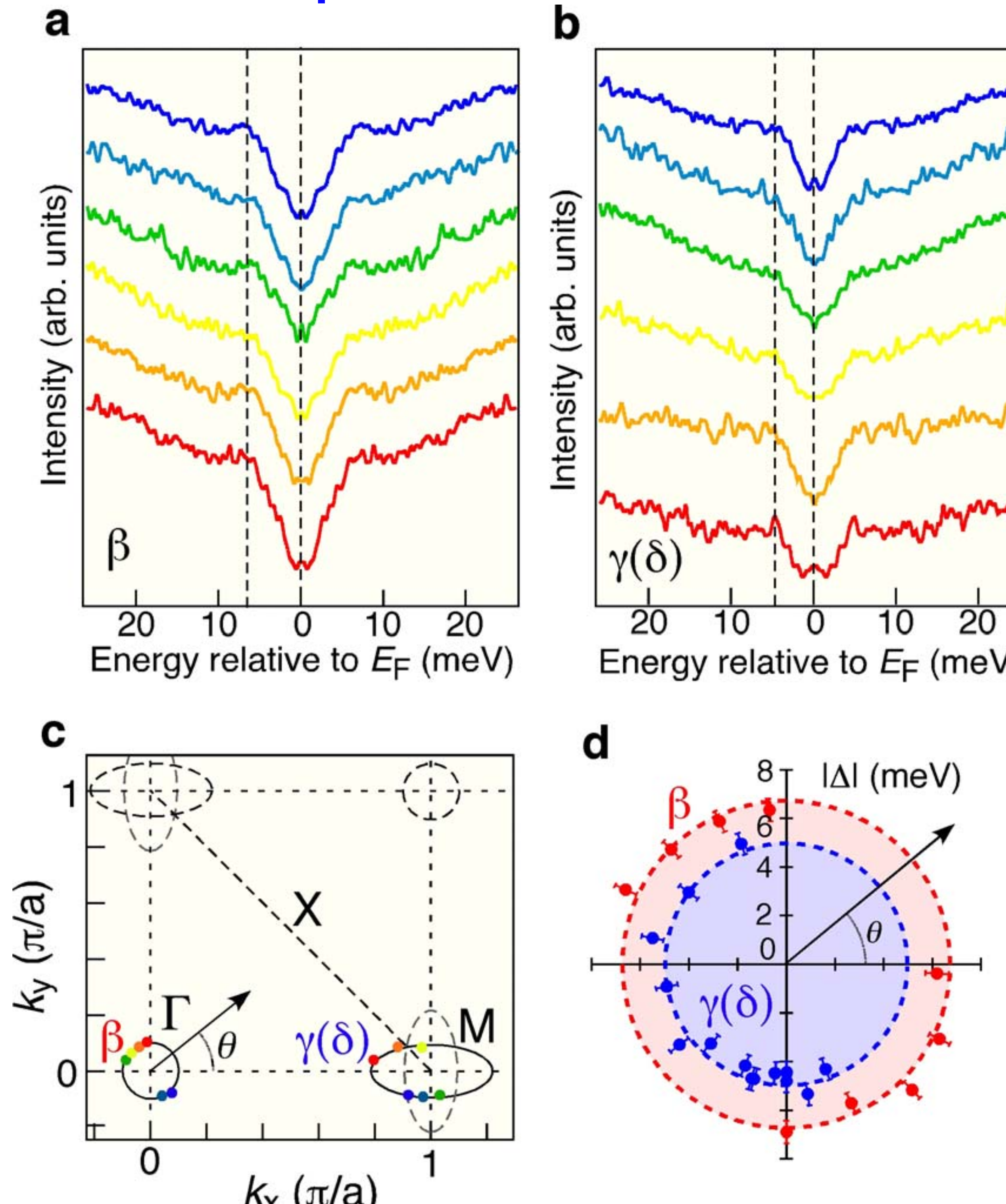
Temperature dependence of the SC gaps



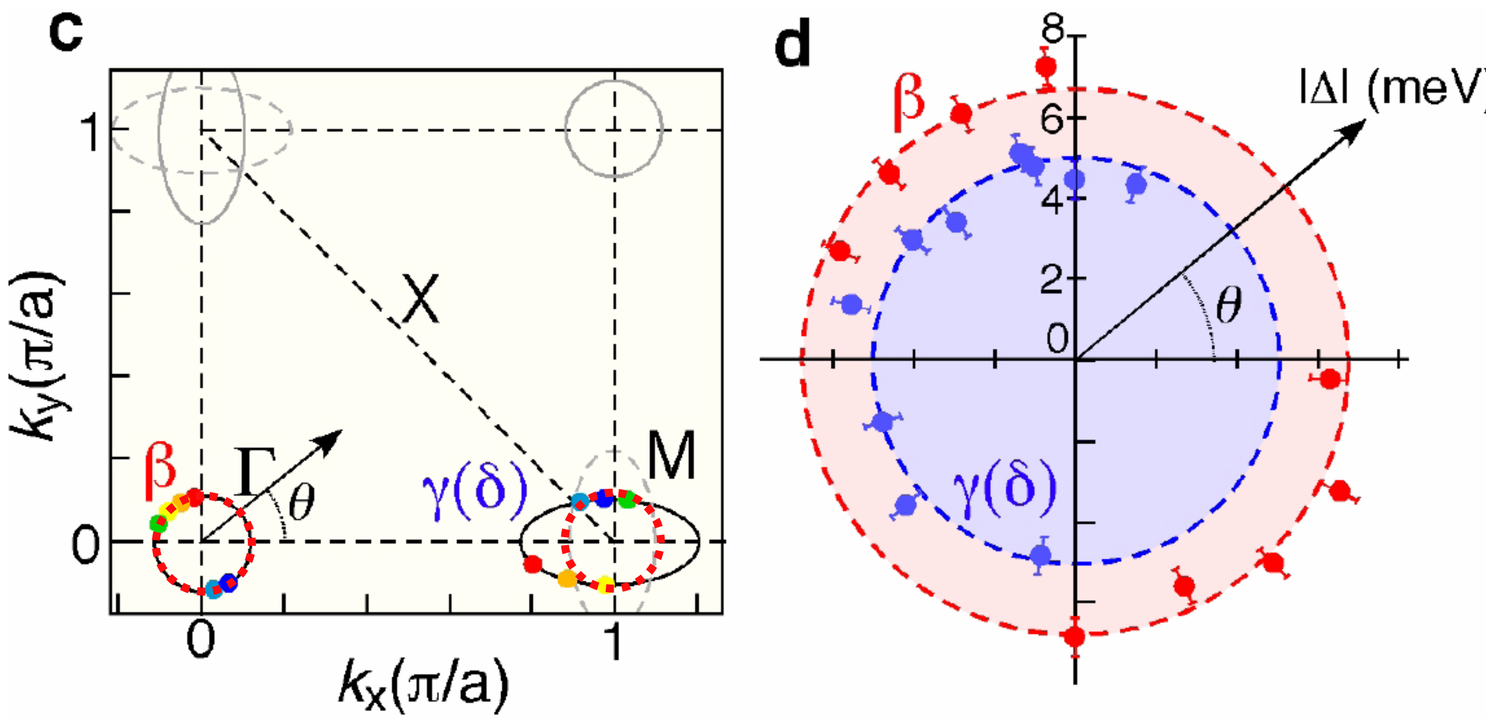
$2\Delta_\beta/k_BT_c = 6$

$2\Delta_\delta/k_BT_c = 4.5$

Momentum dependence of the SC gaps



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



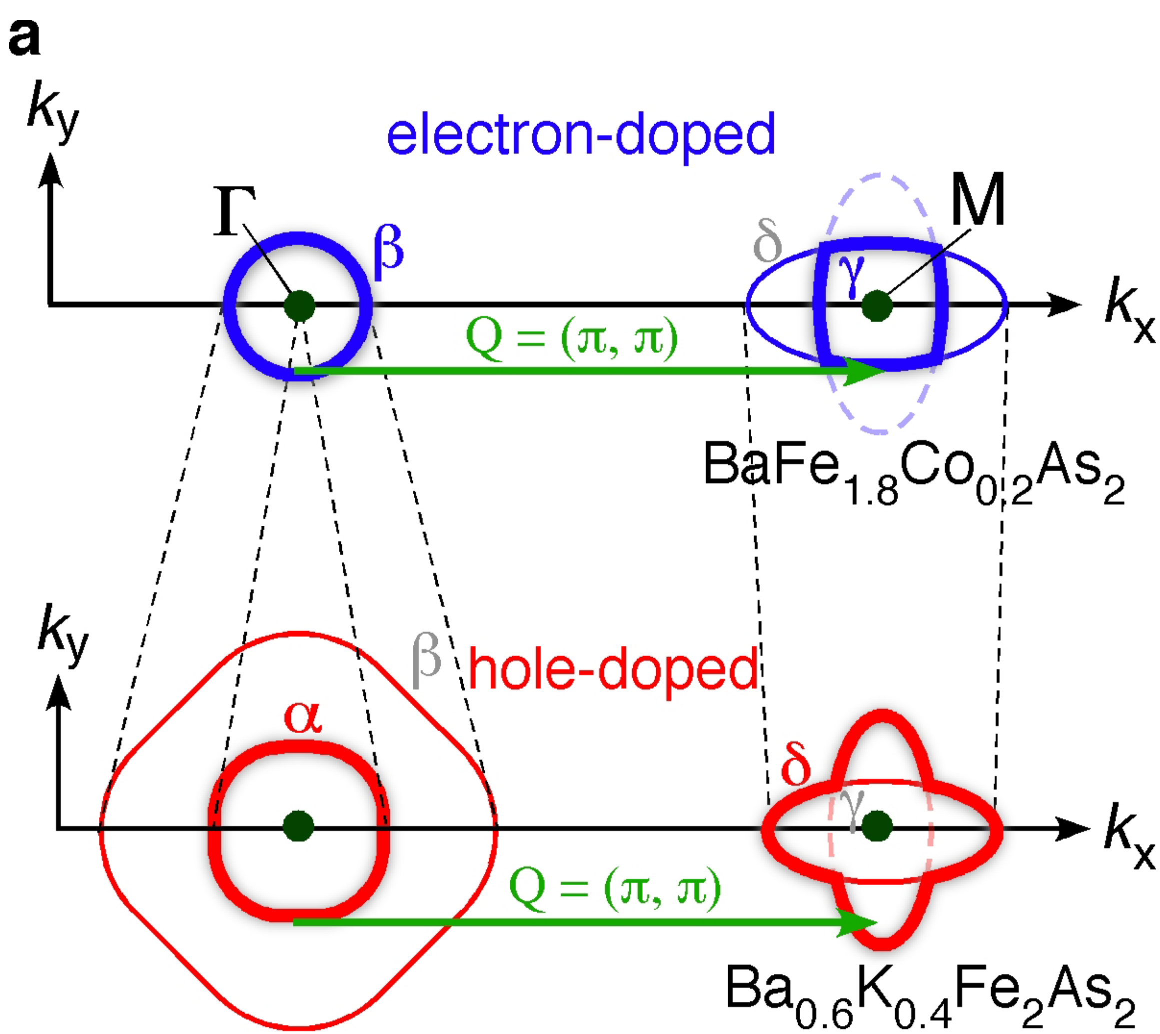
Strong pairing also happens to these FSs!

$2\Delta/k_BT_c$ = 6, 4.5
for β, γ(δ)

K. Terashima *et al.*, PNAS 106, 7330 (2009)

Quasi FS nesting induced strong pairing

$2\Delta_\beta/k_BT_c = 6$



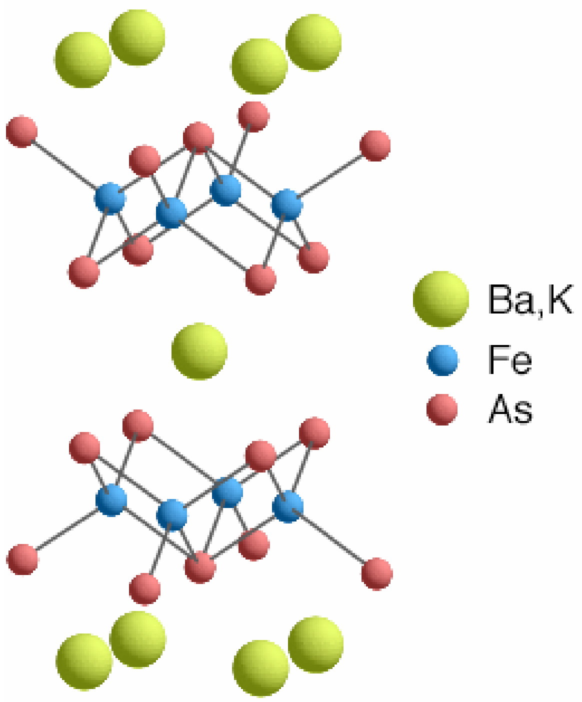
$2\Delta_\beta/k_BT_c = 3.6$

$2\Delta_\alpha/k_BT_c = 7.7$

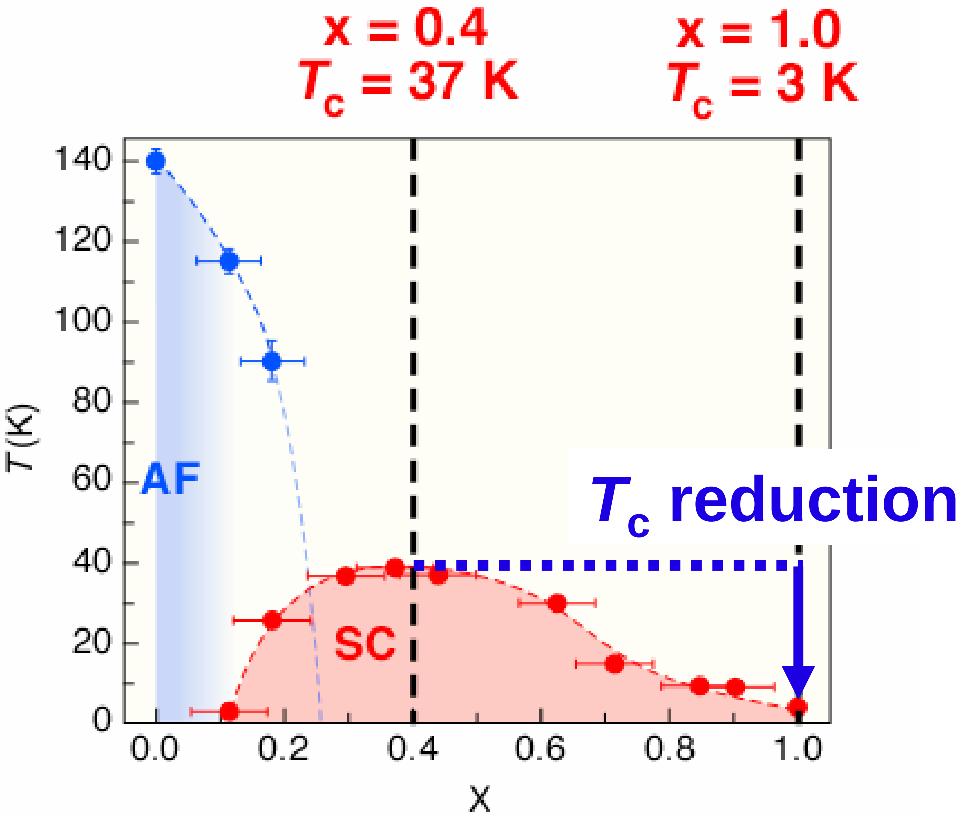
3. Collapse of T_c in heavily hole doped samples

$Ba_{1-x}K_xFe_2As_2$

Crystal structure

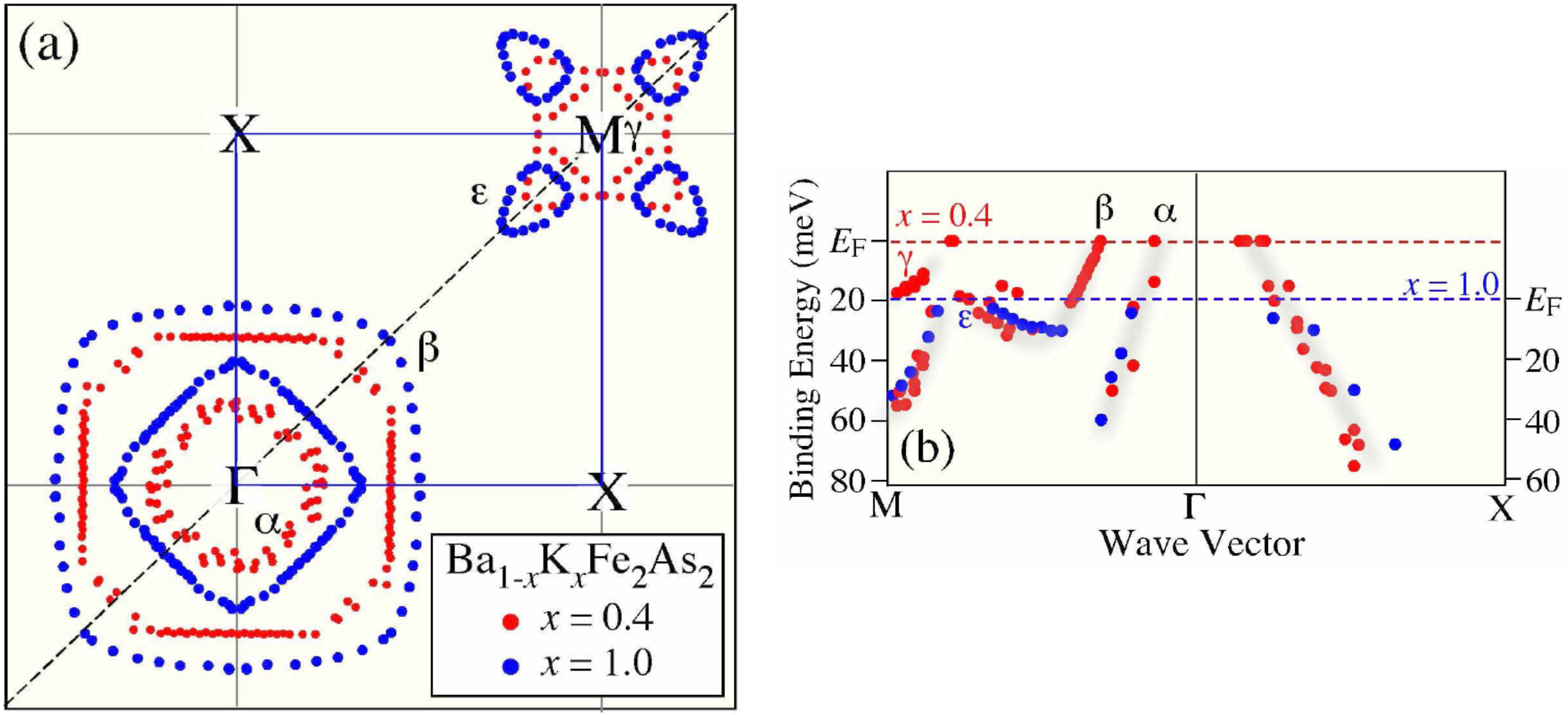


Phase diagram



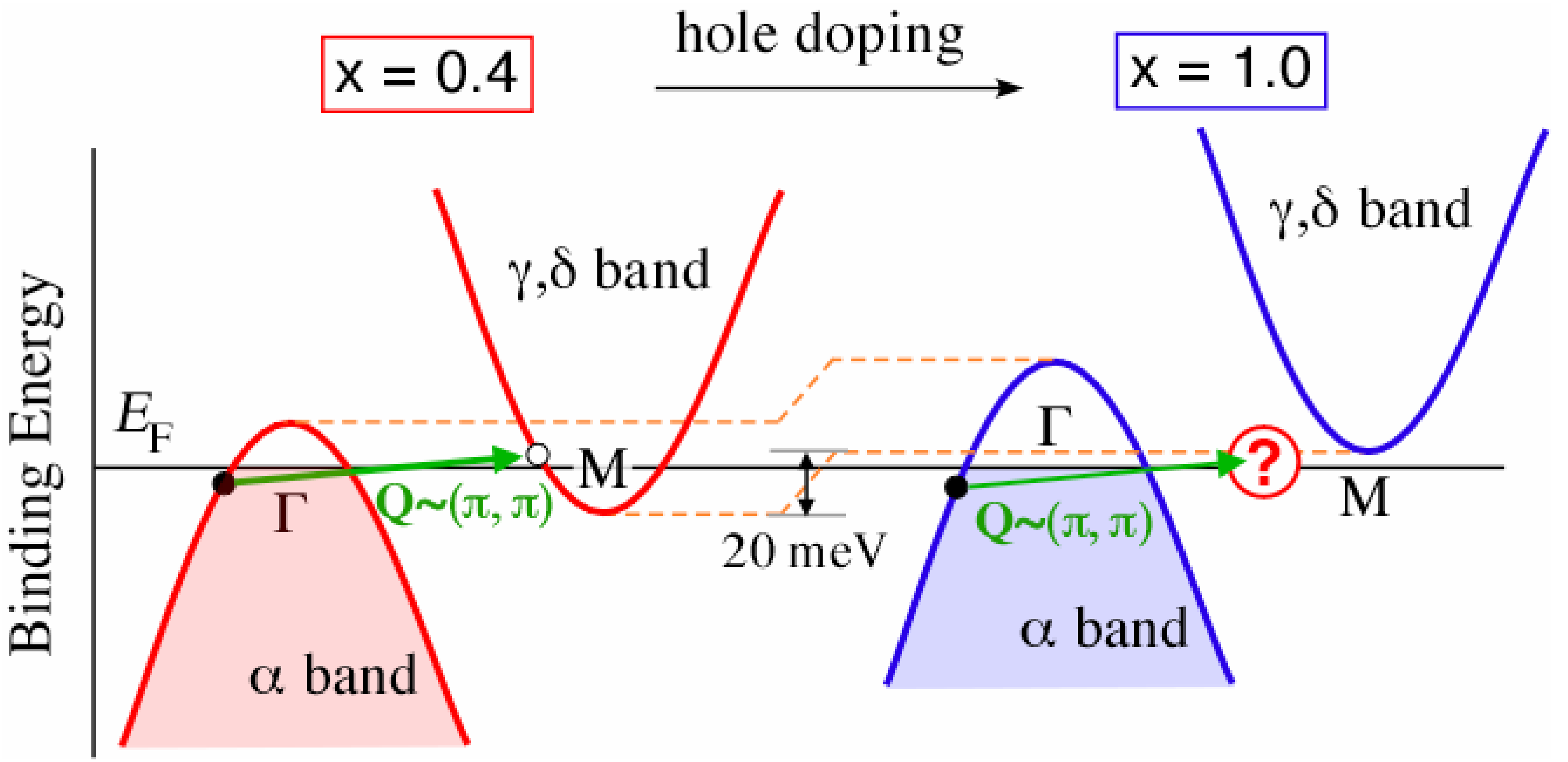
M. Rotter *et al*., Angew. Chem. Int. Ed. **47**, 7949-7952 (2008).

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



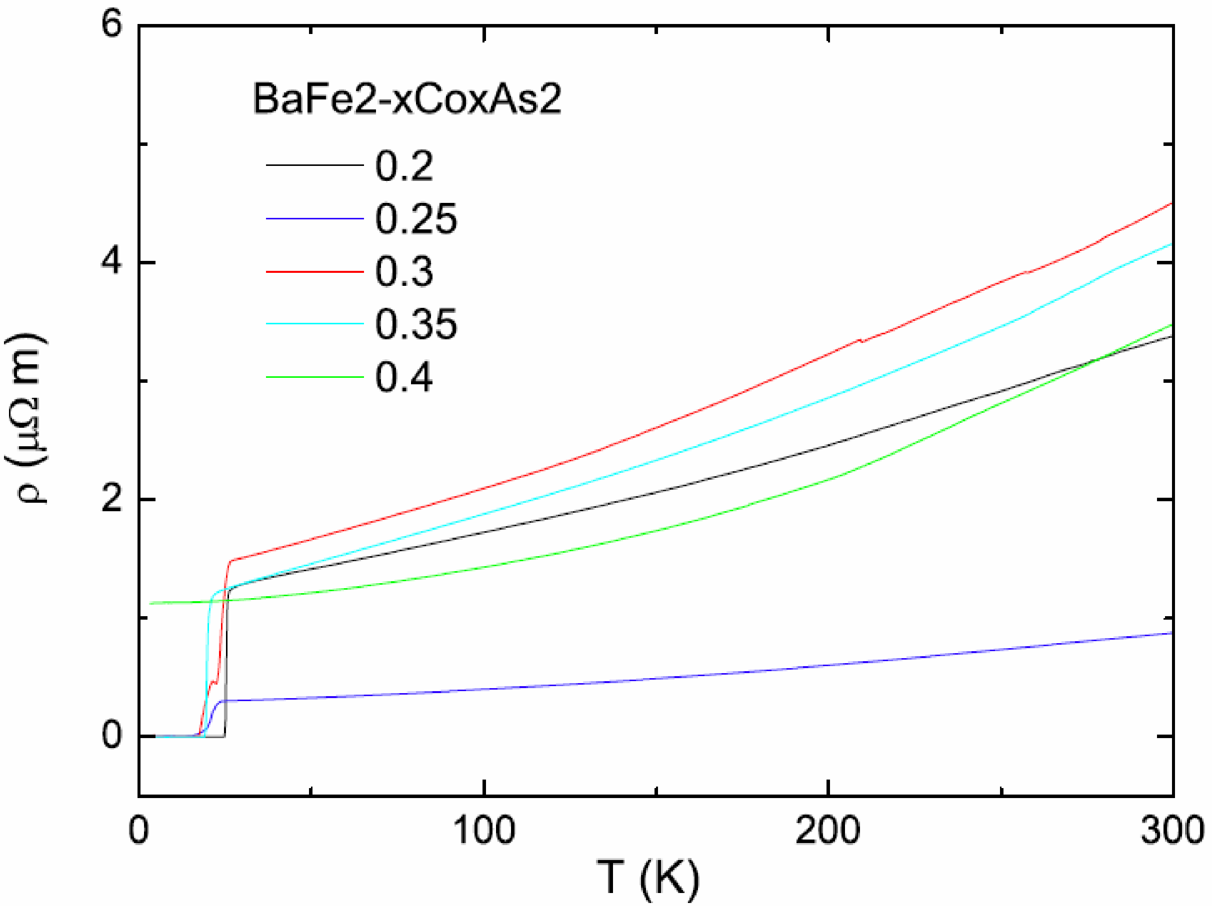
T. Sato *et al.*, PRL 103, 047002 (2009)

Disappearance of electron FS pockets ⟷ collapse of T_c



· Interband scattering via Q_{AF}

4. Disappearance of T_c in heavily electron doped samples

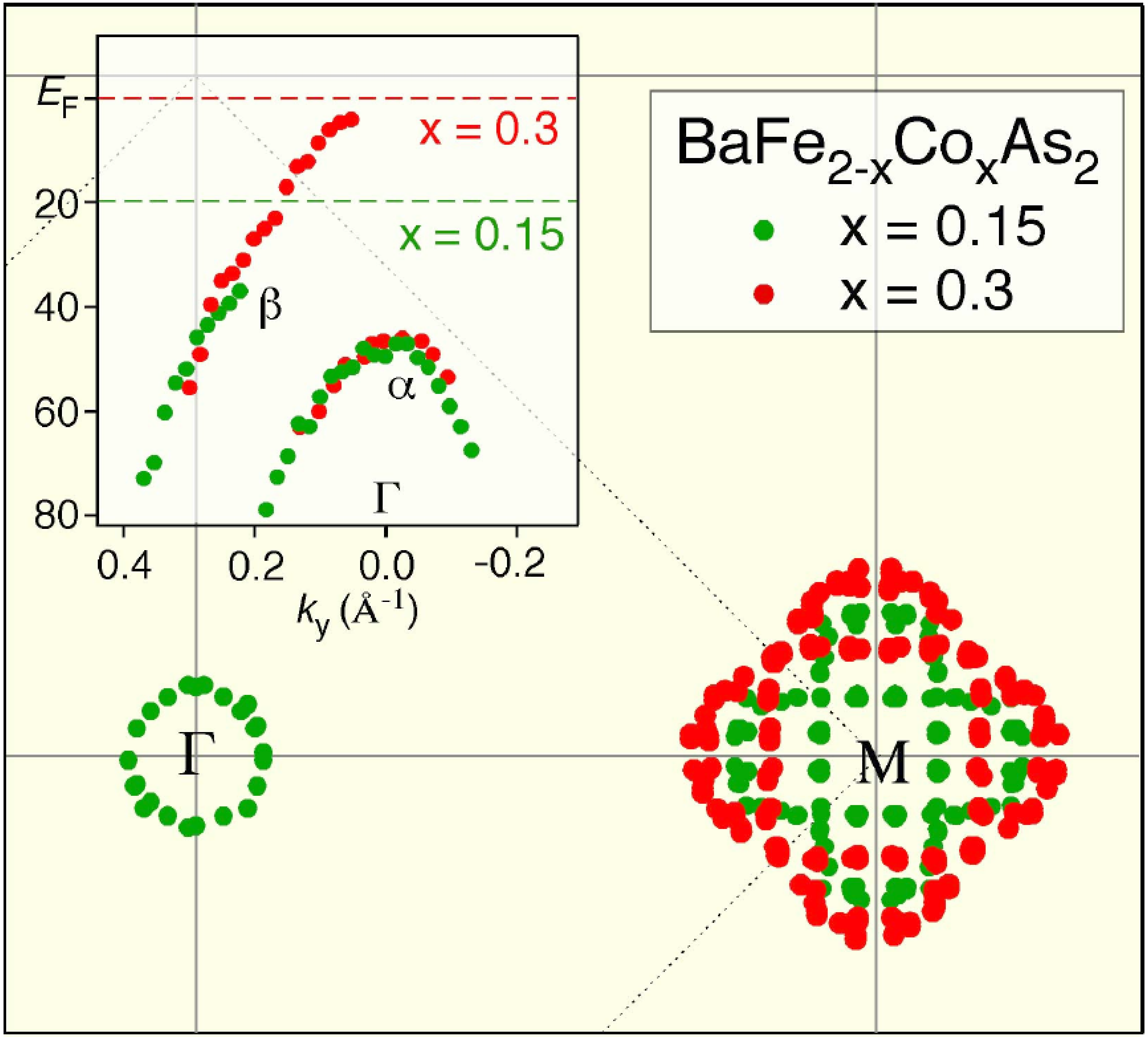


$BaFe_{1.7}Co_{0.3}As_2$

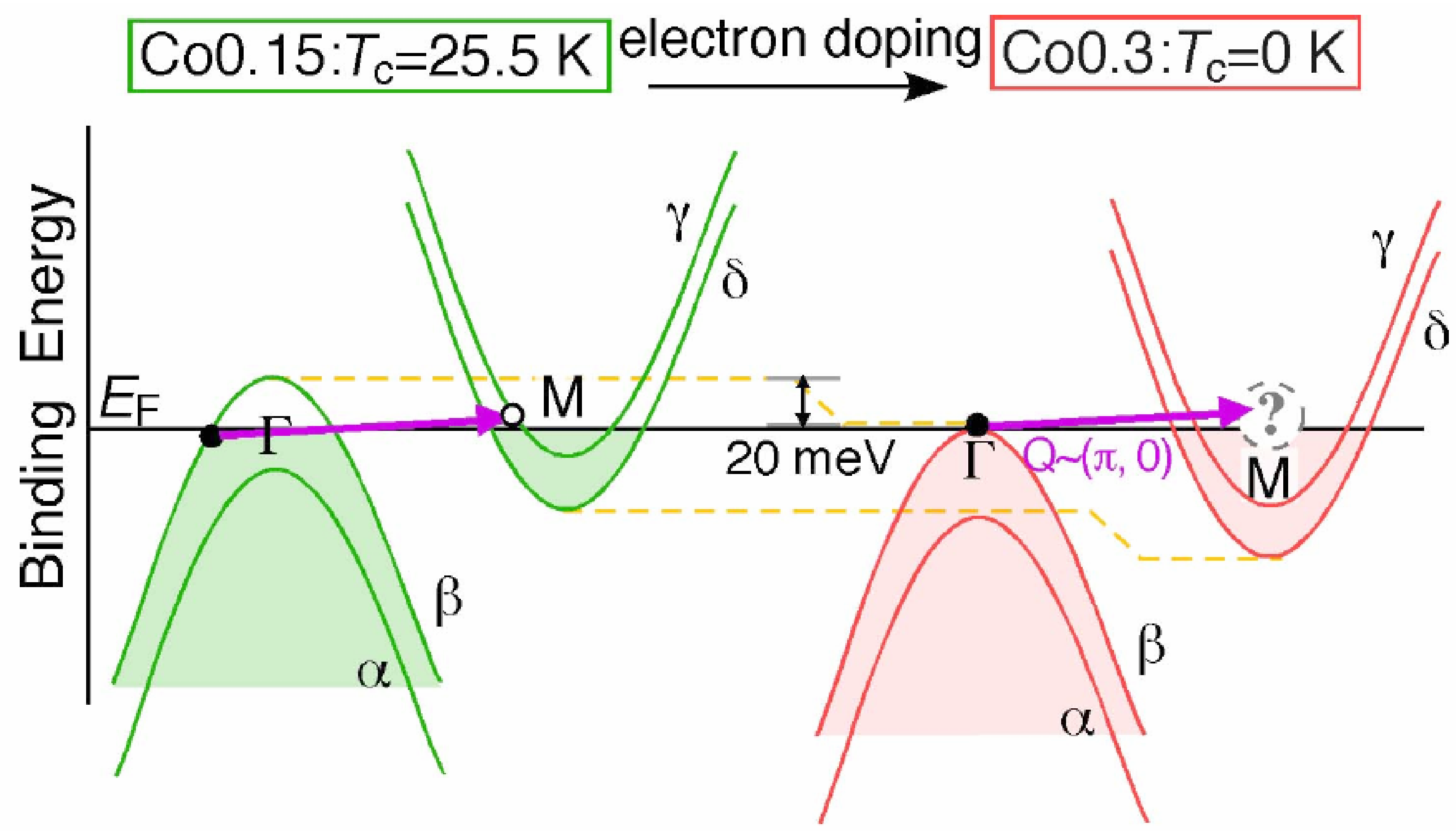
$T_c < 2$ K

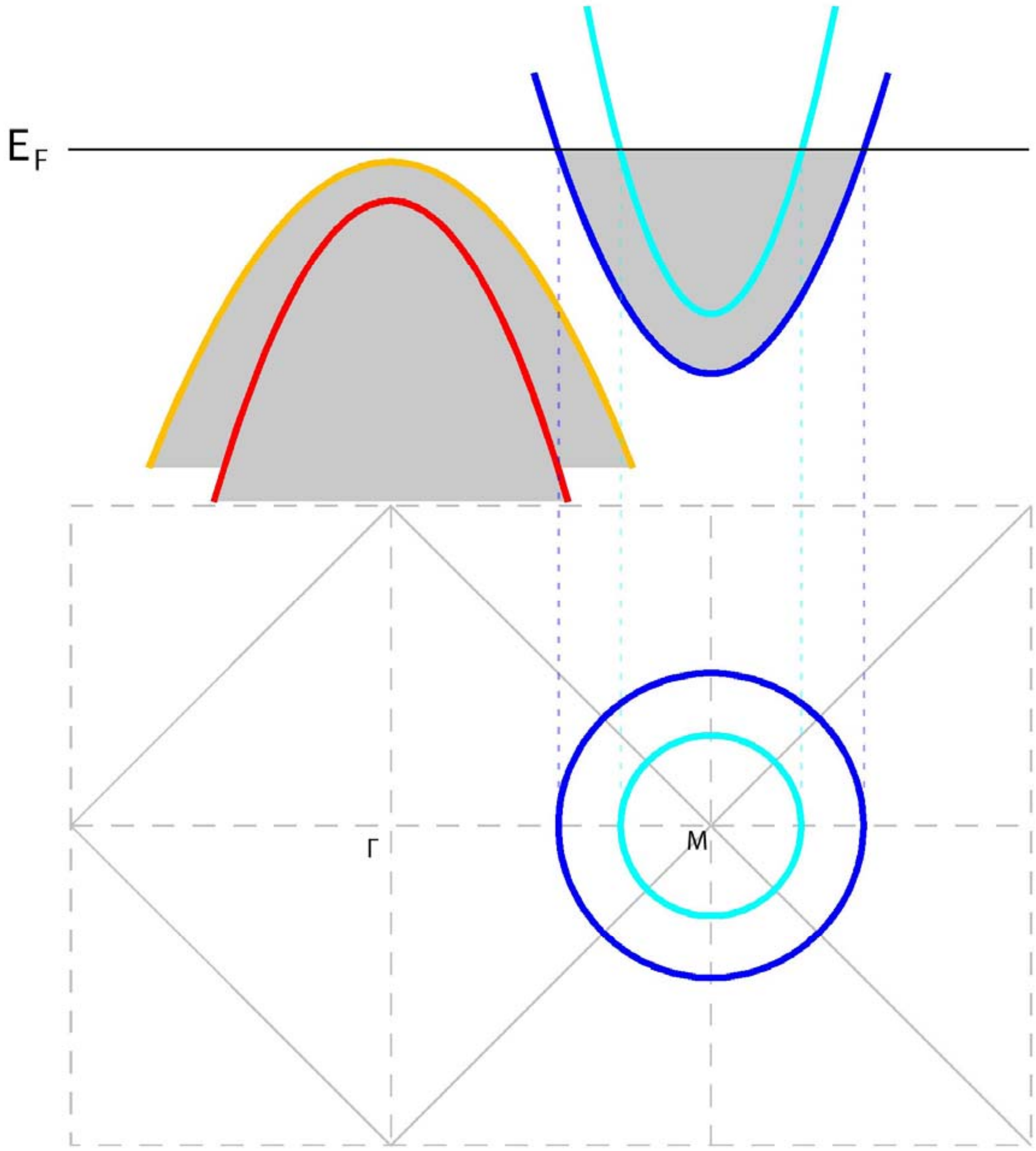
Nominal Co = 0.4

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



Disappearance of hole FS pockets ⟷ collapse of T_c





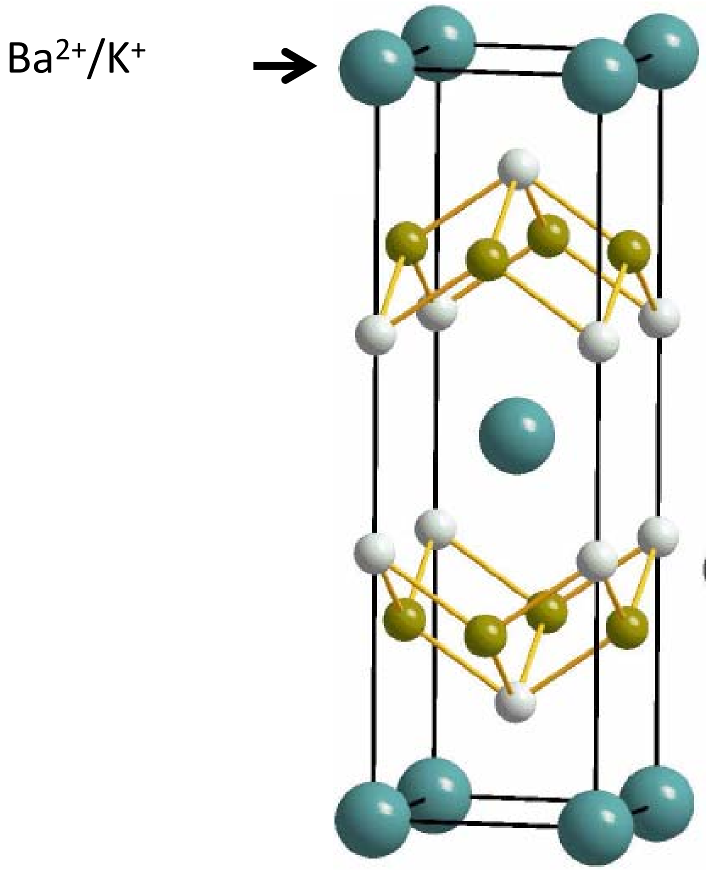
Heavily Electron Doped

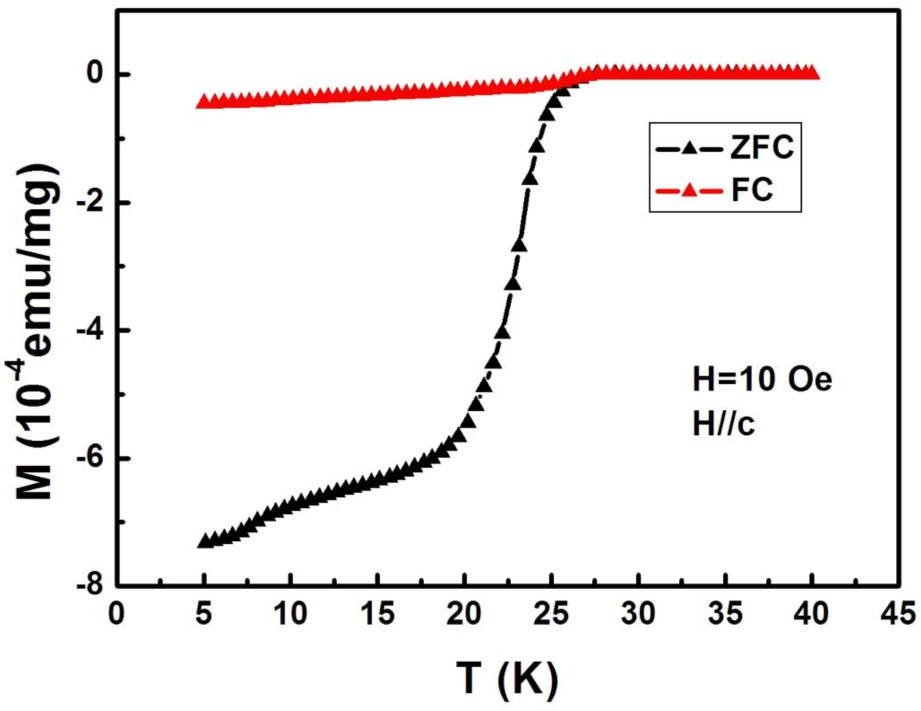
1. Optimal Hole Doped

More realistic view of

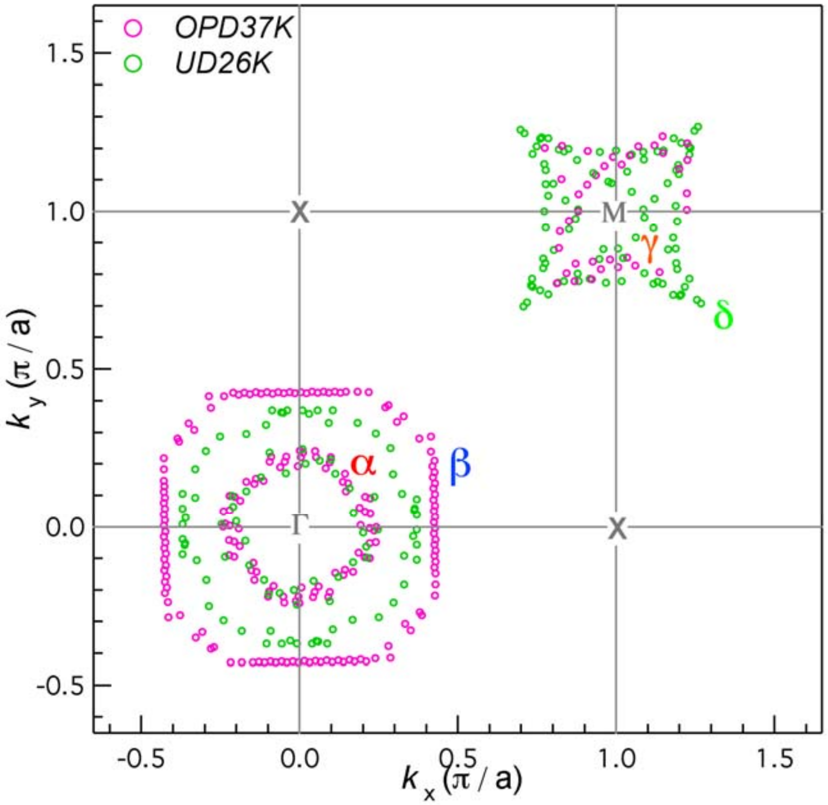
what is happening in pnictides

5. Underdoped $Ba_{0.75}K_{0.25}Fe_2As_2$ (T_c = 26 K)





Comparison between UD and OPD samples

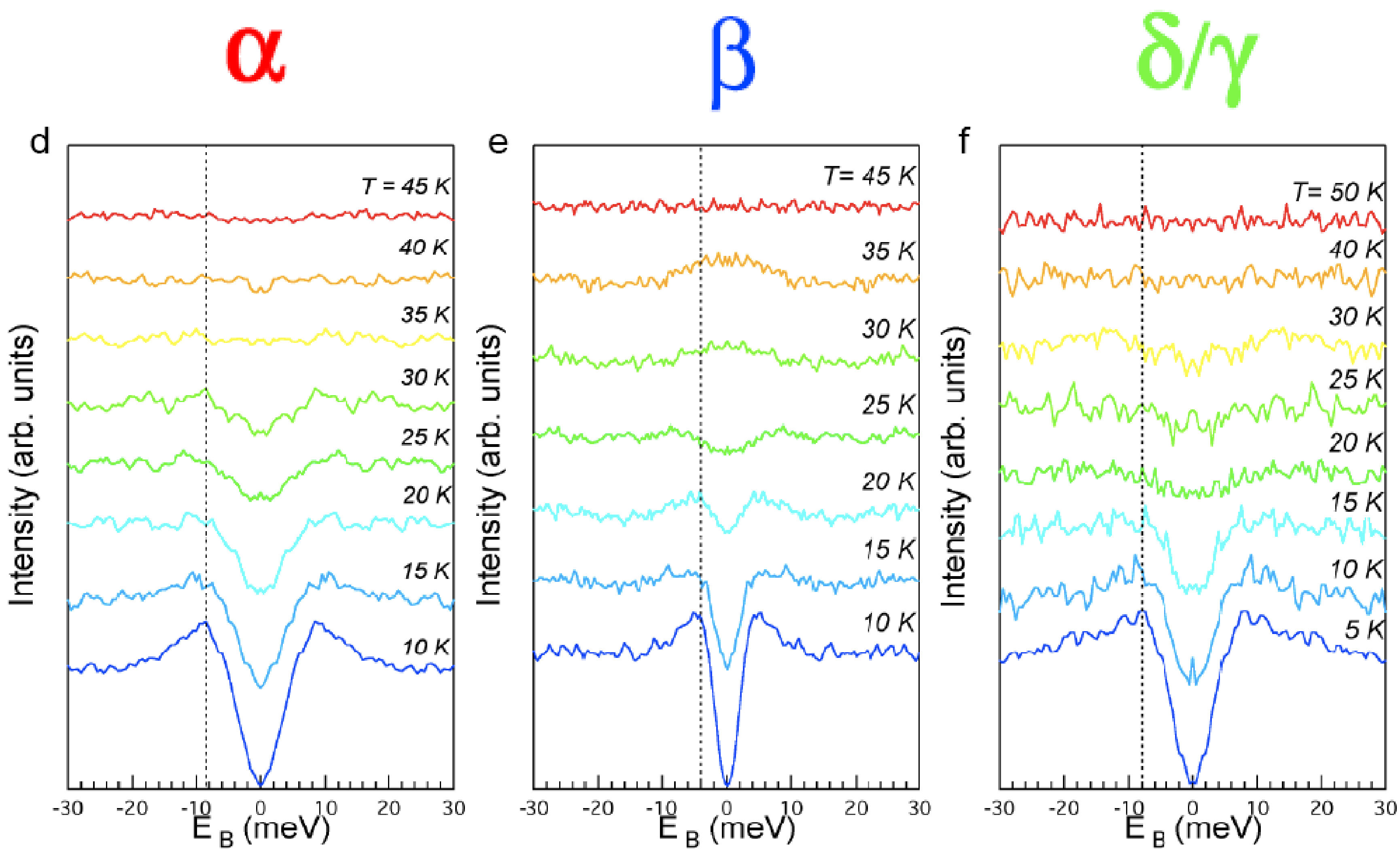


	α	β	γ	δ	α'
OP	~4%	~18%	~2%	~4%	~4%
UD	~4%	~13%	~2%	~6%	~4%

OP : ~40% hole / 2Fe, nominal x = 0.40
UD : ~26% hole / 2Fe, nominal x = 0.25

Luttinger theorem is satisfied in both doping

Superconducting gaps and their T-dependence

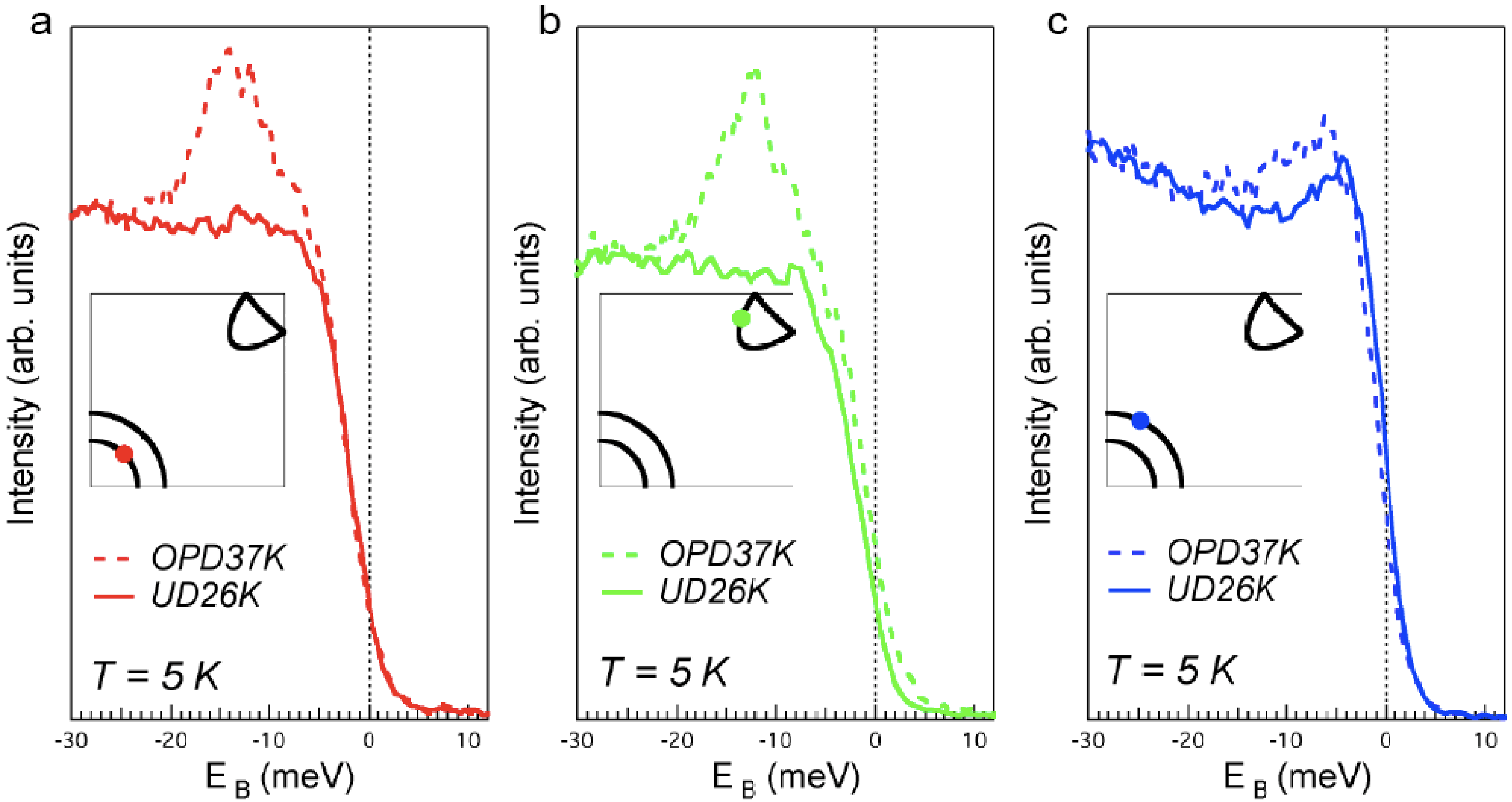


Δ_α ~ 8 meV

Δ_β ~ 4 meV

$\Delta_{\delta/\gamma}$ ~ 8 meV

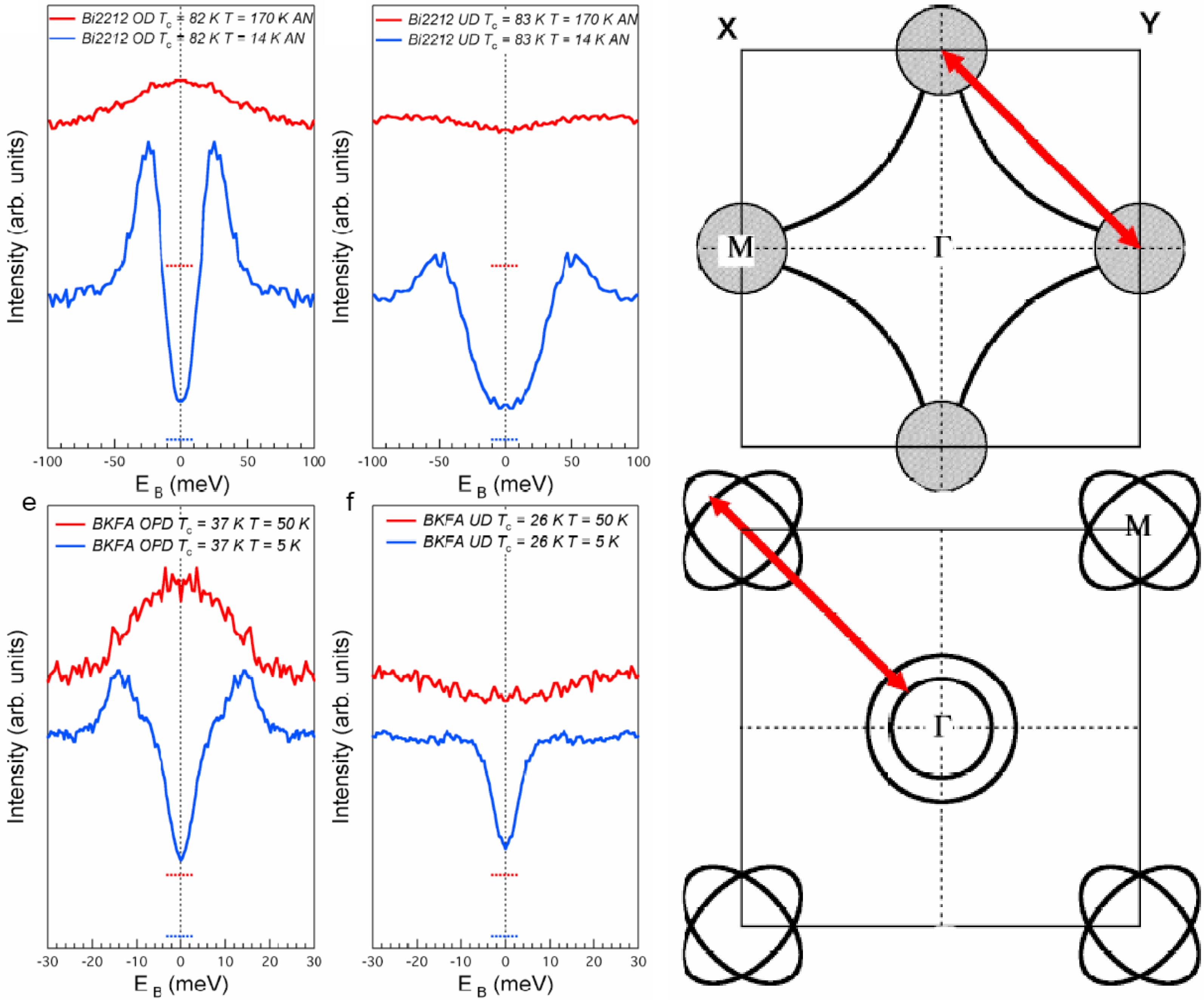
FS-dependent QP suppression in underdoped pnictides



Antinode in cuprates *vs* nested FS in pnictides (hot spots)

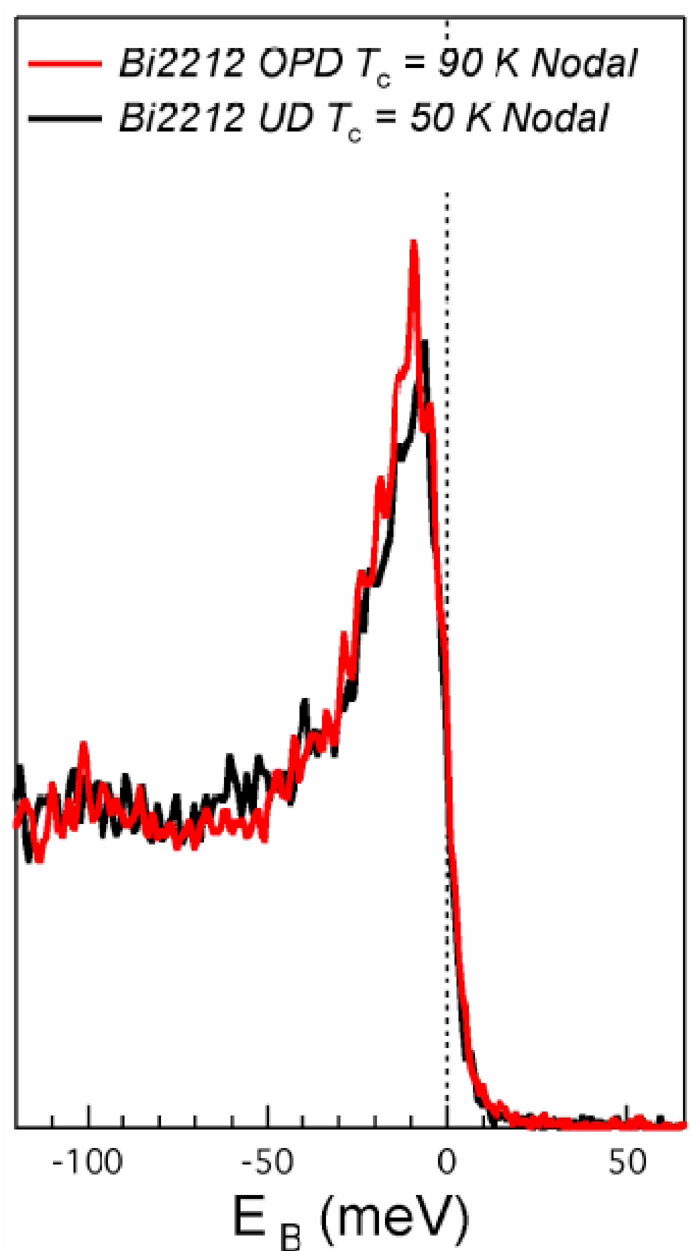
Cuprates

Pnictides

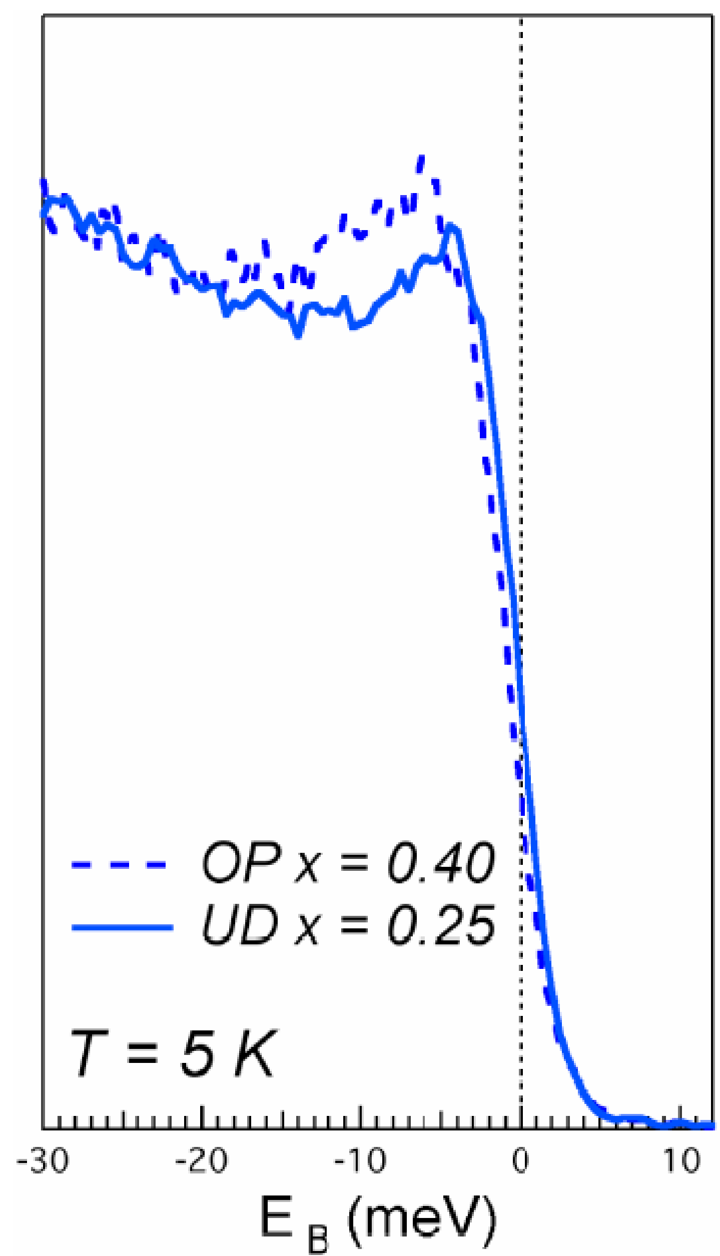


Node in cuprates *vs* β band in pnictides (cold spots)

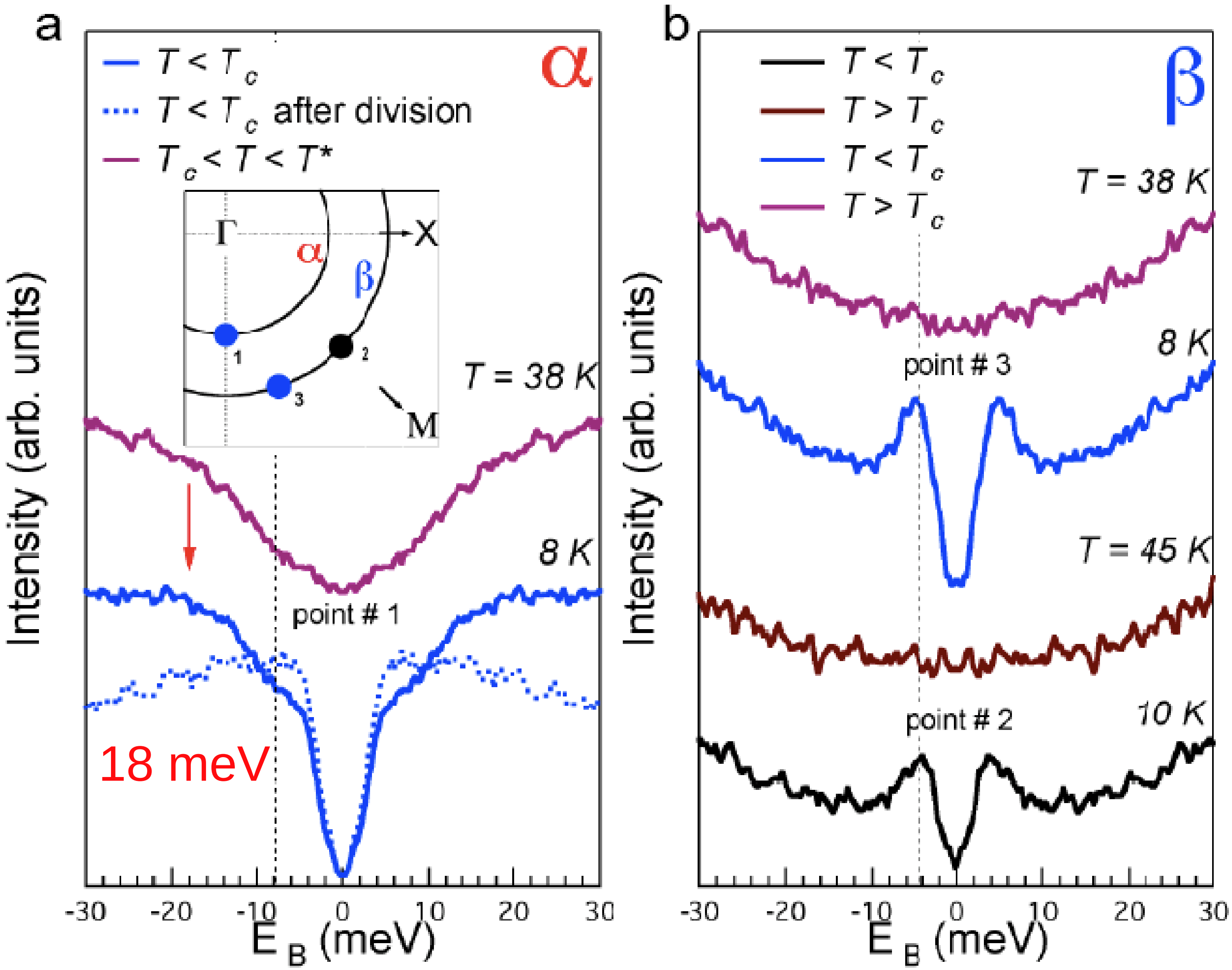
Cuprates



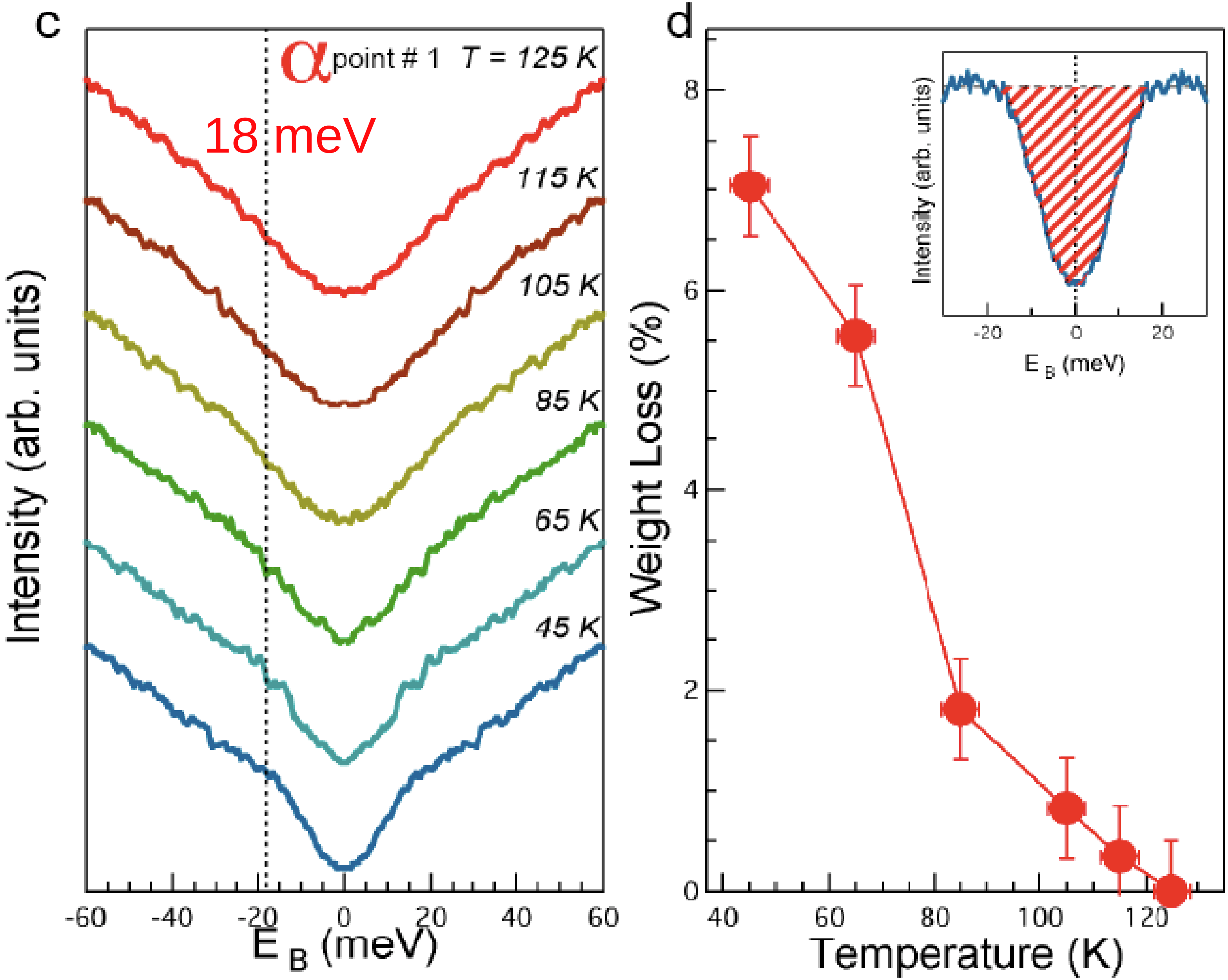
Pnictides



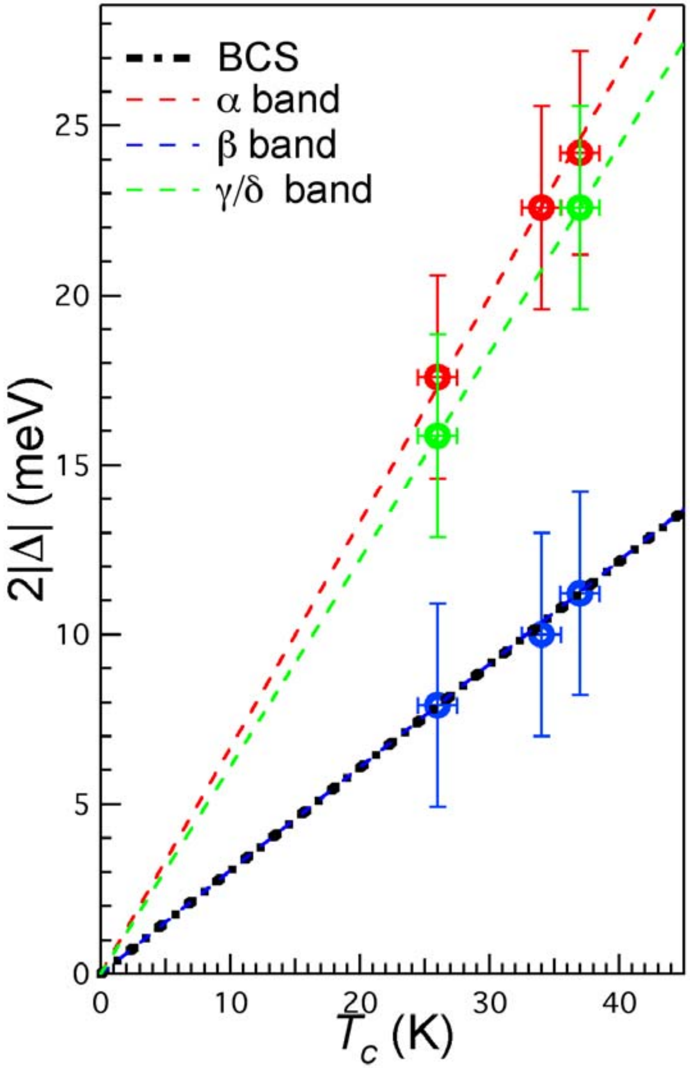
A distinct pseudogap emerges on the nesting FS region



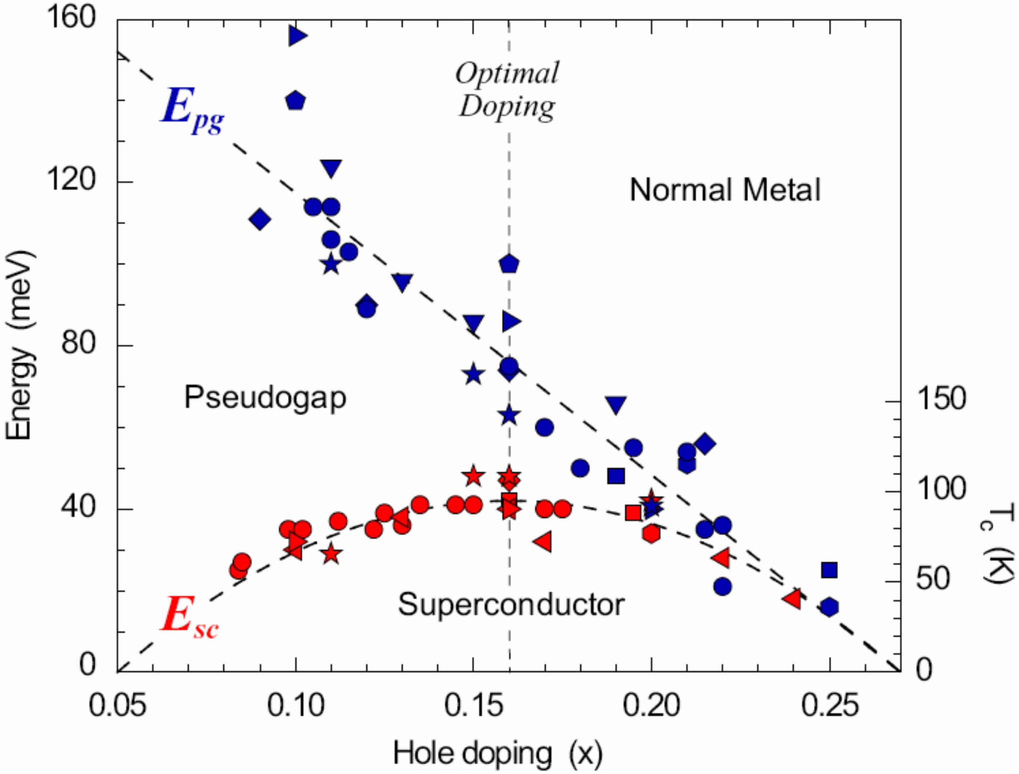
T-dependent measurement of “pseudogap” on α band



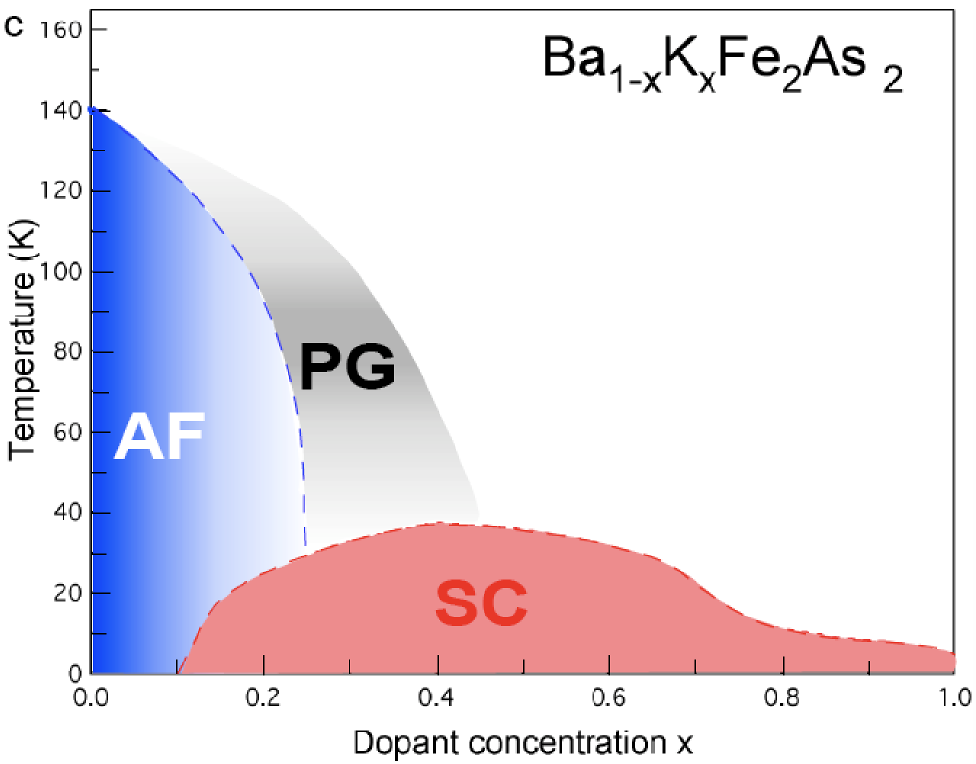
Superconducting gaps scale with T_c

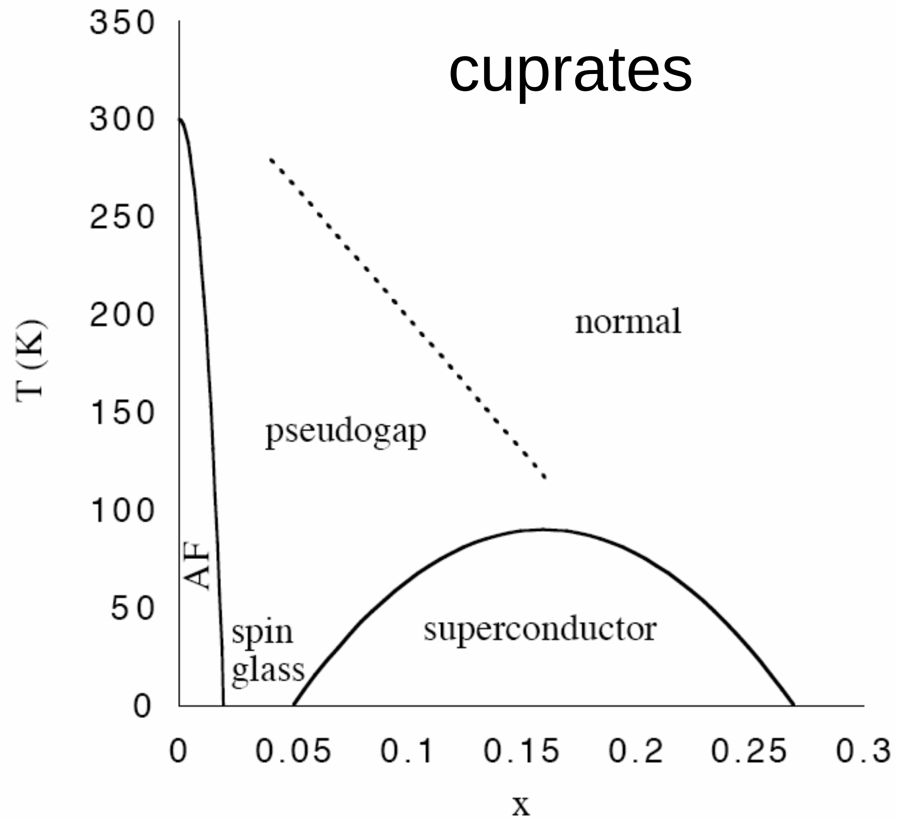


cuprates



Schematic diagram of hole-doped pnictides





Conclusions

- **Our ARPES results support *s*± pairing**
- **Inter-FS scatterings play a crucial role in paring**
- **Fermi surface near-nesting enhances pairing**
- **In underdoped pnictides, SC gaps scale with Tc**
- **A distinct pseudogap emerges at the nesting FS regions, competing with SC**
- **Unified picture for pnictides and cuprates:**

AF fluctuations?