

Oscillations quantiques, surface de Fermi et état normal des Cuprates



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LNCMI



Laboratoire National des Champs Magnétiques Intenses

GdR MICO - Dinard - 07 décembre 2010



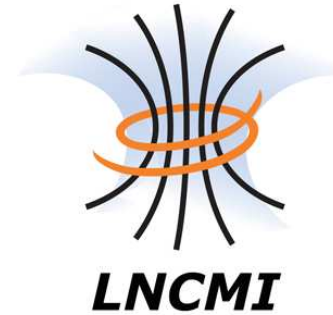
Collaborations

S. Lepault (Doc.)

S. Badoux (Doc.)

D. LeBoeuf (PostDoc.)

J. Levallois (Ancien Doc.)



D. Vignolles

A. Audouard

C. Proust



L. Taillefer

N. Doiron-Leyraud

D. LeBoeuf

J-B Bonnemaïson



D. Bonn

R. Liang

W. Hardy

B.J. Ramshaw



N. Hussey

T. Carrington

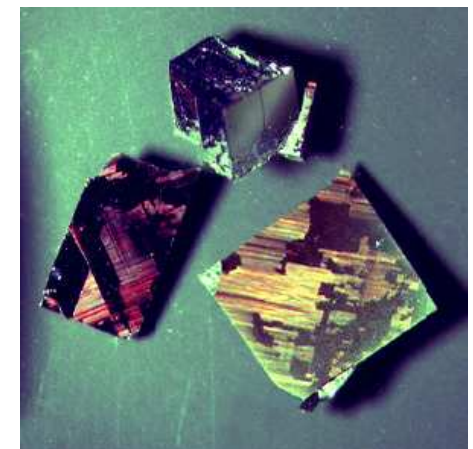
J.D. Fletcher

A.F. Bangura



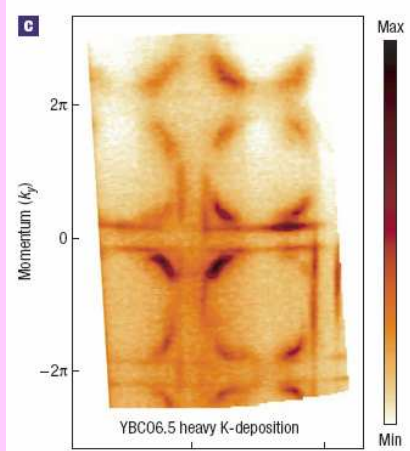
University of
St Andrews

A.P. Mackenzie



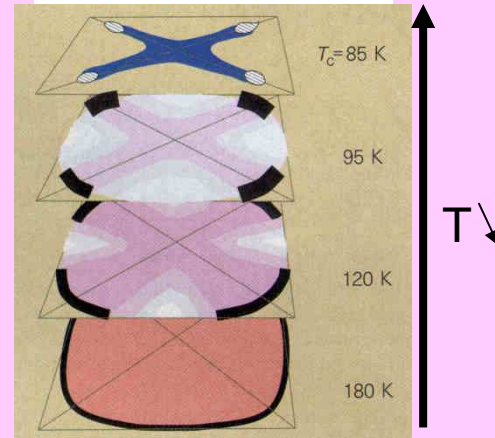
Surface de Fermi des cuprates

ARPES (YBCO_{6.5})



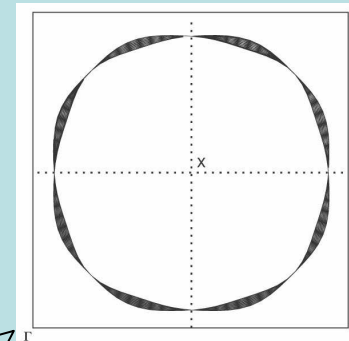
M.A Hossain *et al.*, Nature Phys'08

'Arcs de Fermi'

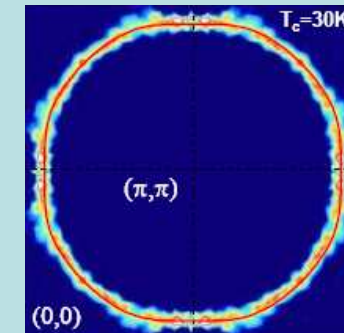


M. Norman *et al.*, Nature'98

Tl₂Ba₂CuO_{6+δ}
p~0.25

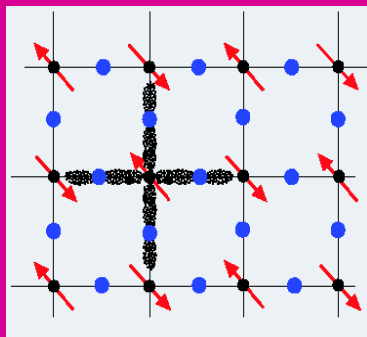


Hussey *et al.*, Nature'03

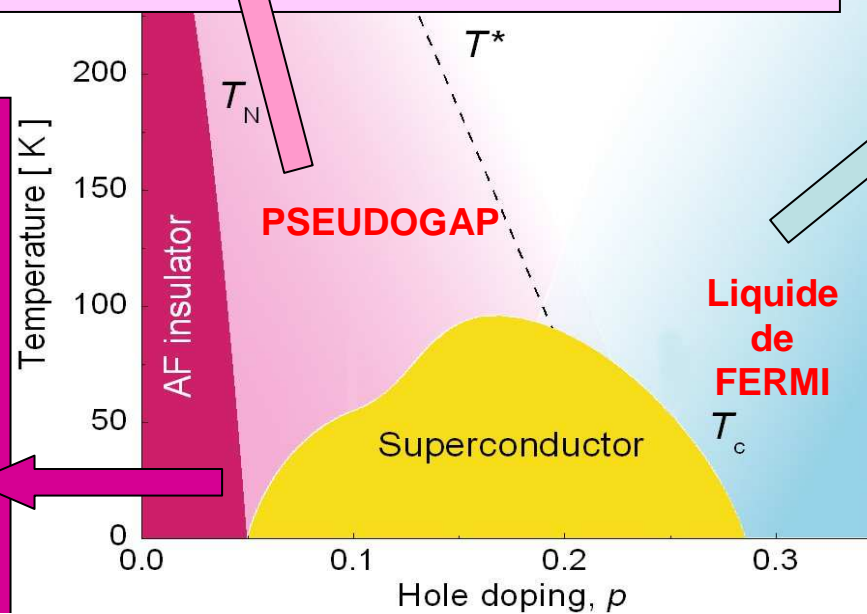


Platé *et al.*, PRB'05

Isolant de Mott



1/2 remplissage
Forte répulsion e-e
Ordre AF

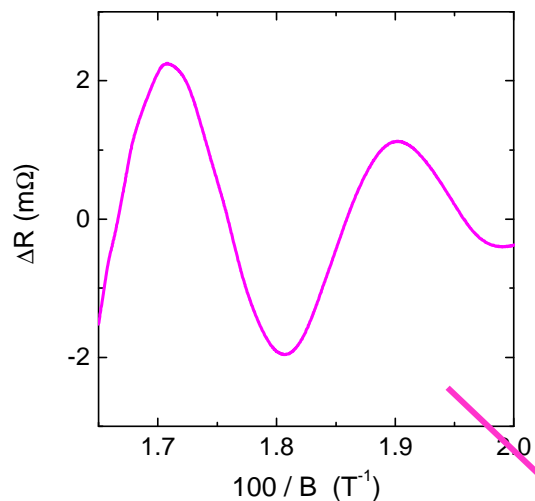


1) Mécanisme d'appariement à l'origine de la supra ?

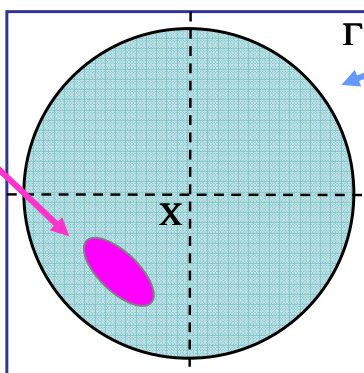
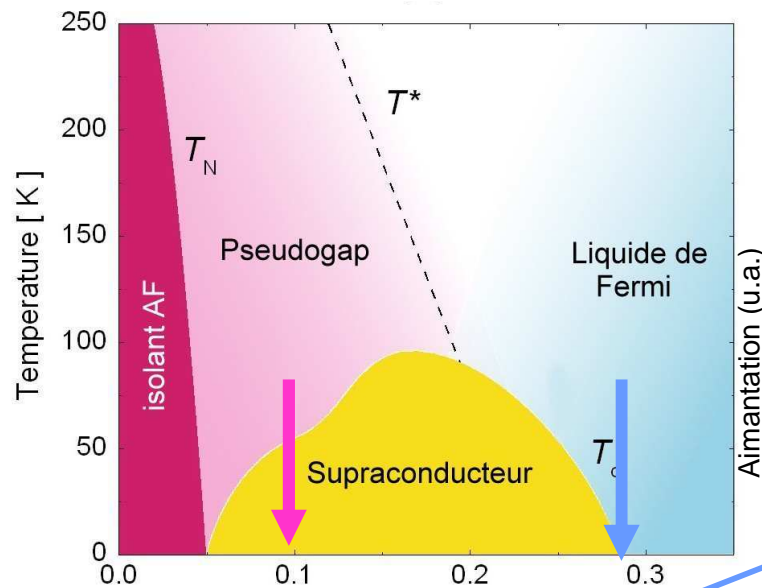
2) Nature de l'état normal à basse température ?

Supraconducteurs à haute T_c : Oscillations quantiques

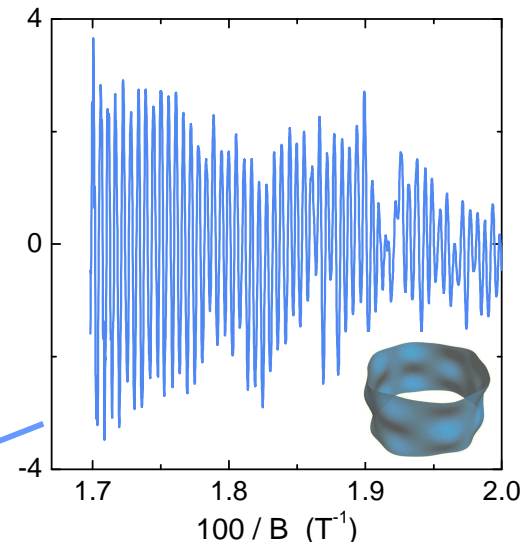
Sous-dopé
 $\text{YBa}_2\text{Cu}_3\text{O}_{6.5}$



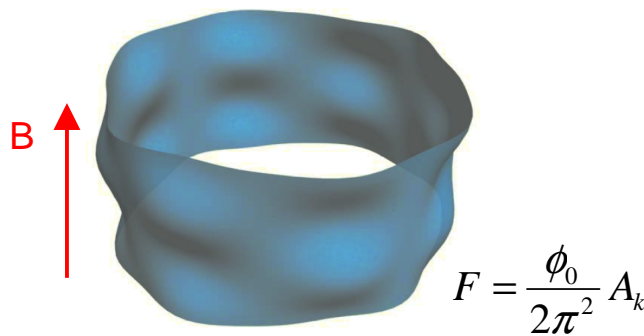
N. Doiron-Leyraud et al, Nature'07



Sur-dopé
 $\text{Tl}_2\text{Ba}_2\text{CuO}_{6+\delta}$



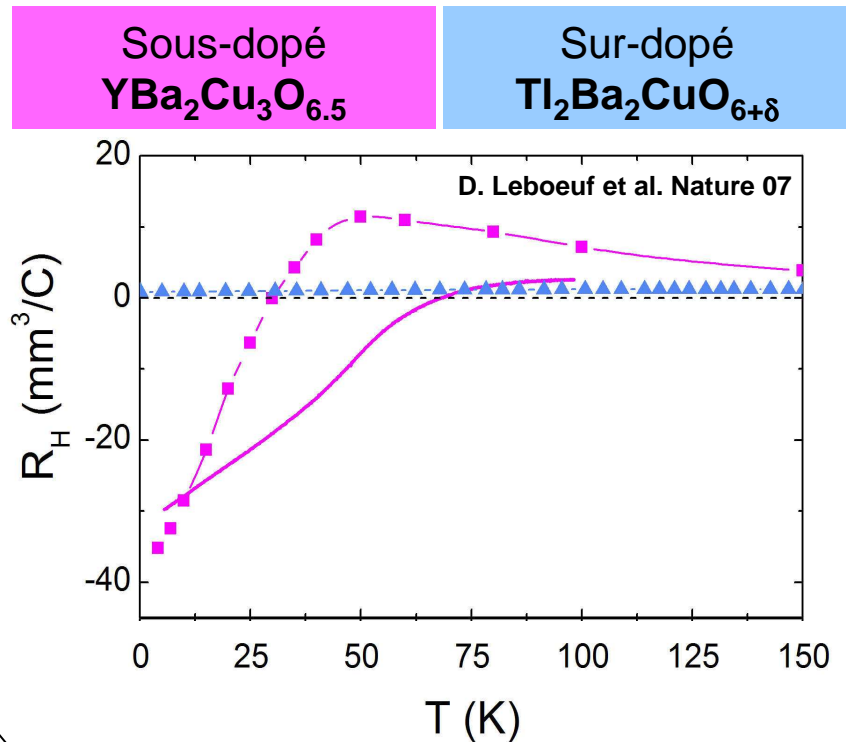
B. Vignolle et al, Nature'08



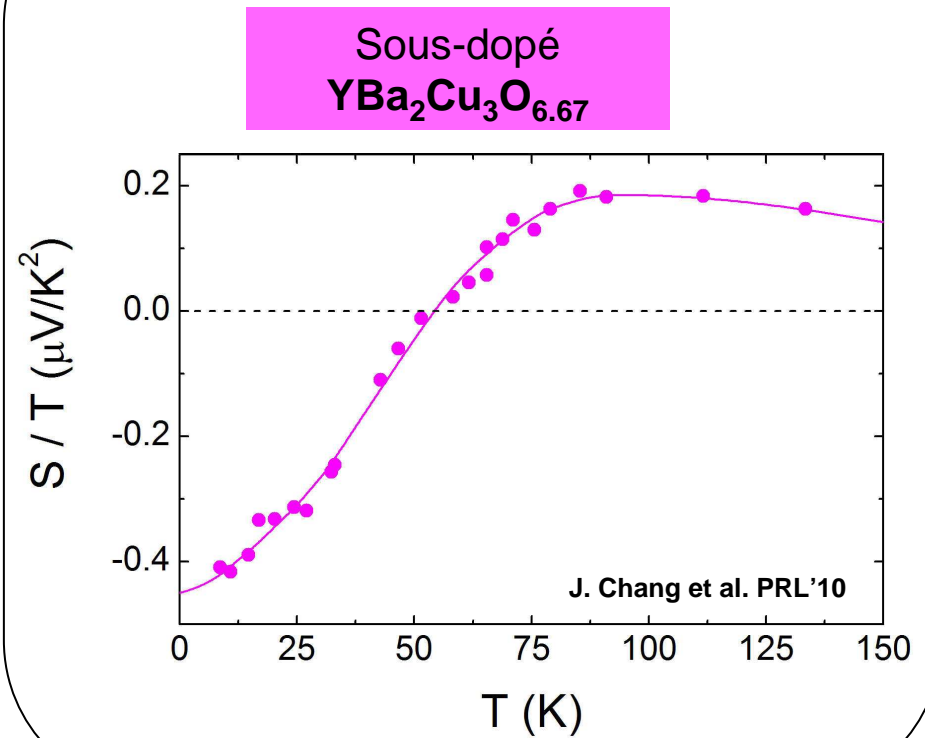
Changement drastique de la topologie de la SF avec le dopage

Supraconducteurs à haute T_c : Reconstruction de la SF

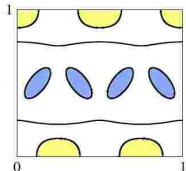
Effet Hall



Effet Seebeck

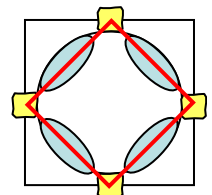


Transport de type électron à basse T



Reconstruction de la grande SF en poches d'électron et de trou

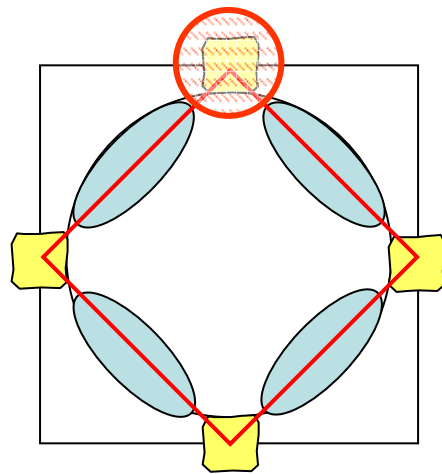
→ Ordre en compétition/coexistant avec la supra



Reconstruction de la Surface de Fermi : différents scénarios

AF / d-DW order

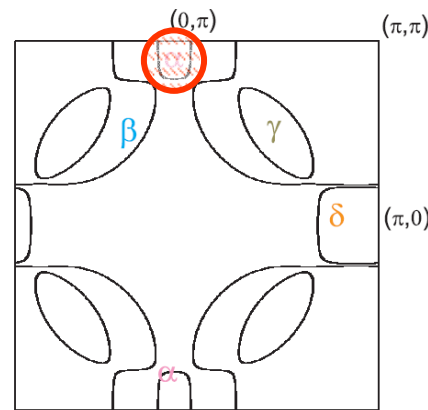
(Rice, Chakravarty)



$$Q=(\pi, \pi)$$

(Field induced) SDW

(Sachdev, Harrison)

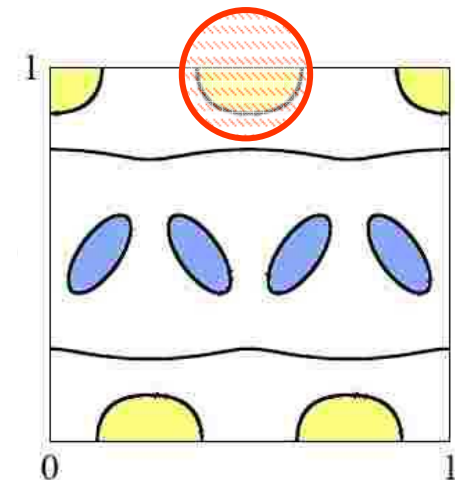


$$Q=(\pi \pm \delta, \pi)$$

Stripes

(Millis and Norman, Vojta)

CDW / SDW



$$Q=(3\pi/4, \pi)$$

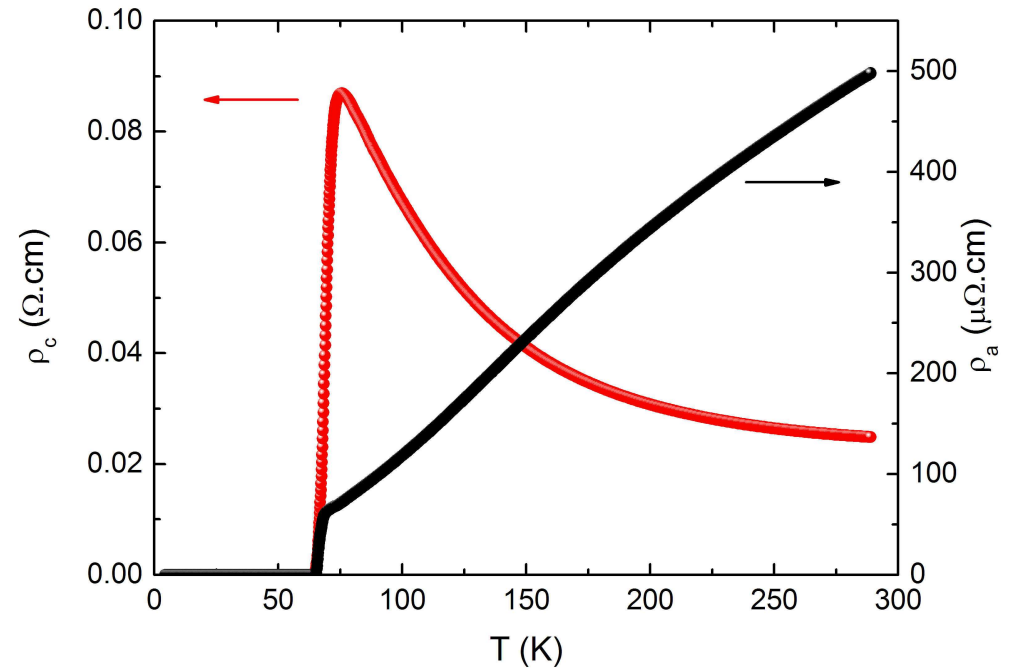
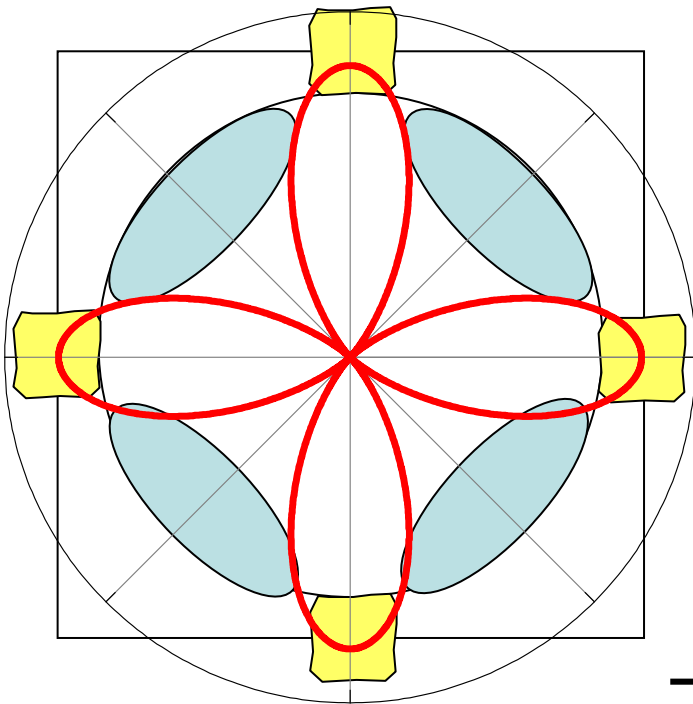
Fermi surface reconstruction \Rightarrow electron pocket at the anti-node

Interlayer hopping integral

$$\sigma_c \propto t_{\perp}^2$$

For a tetragonal cuprate material:

$$t_{\perp}(k) = \frac{t_{\perp}}{4} [\cos(k_x a) - \cos(k_y a)]^2$$



Transport selon c isolant jusqu'à T_c !

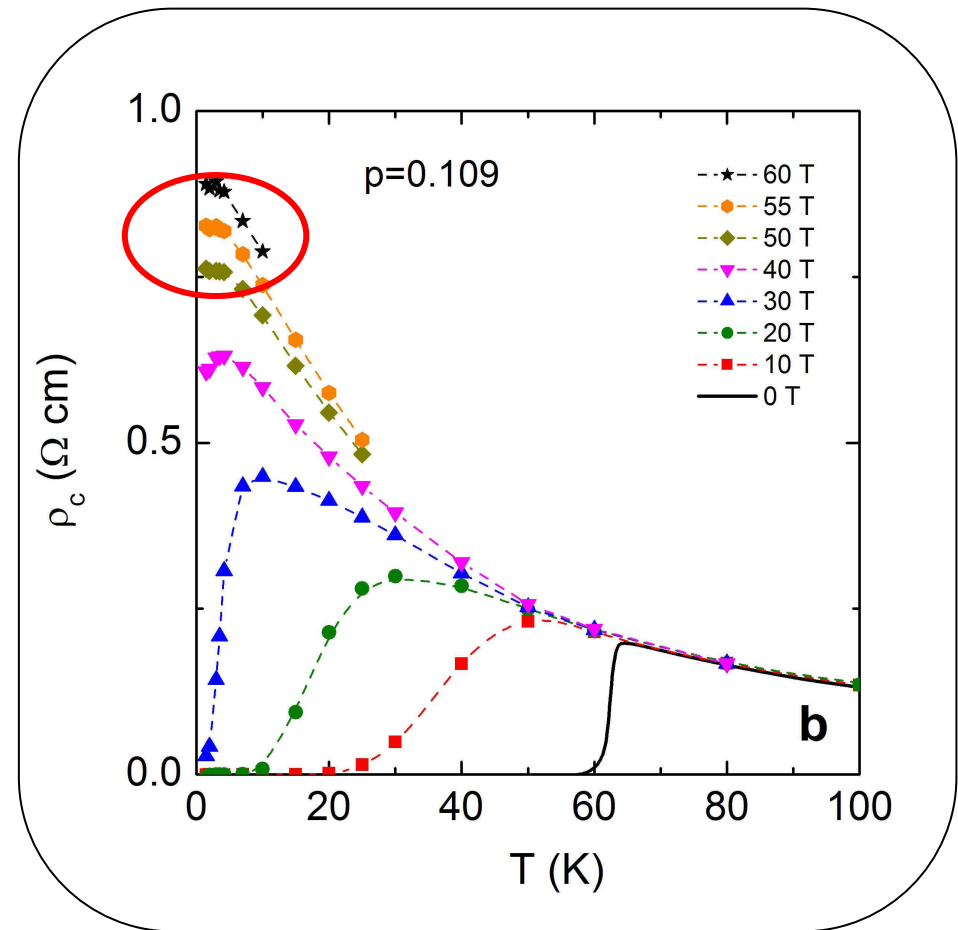
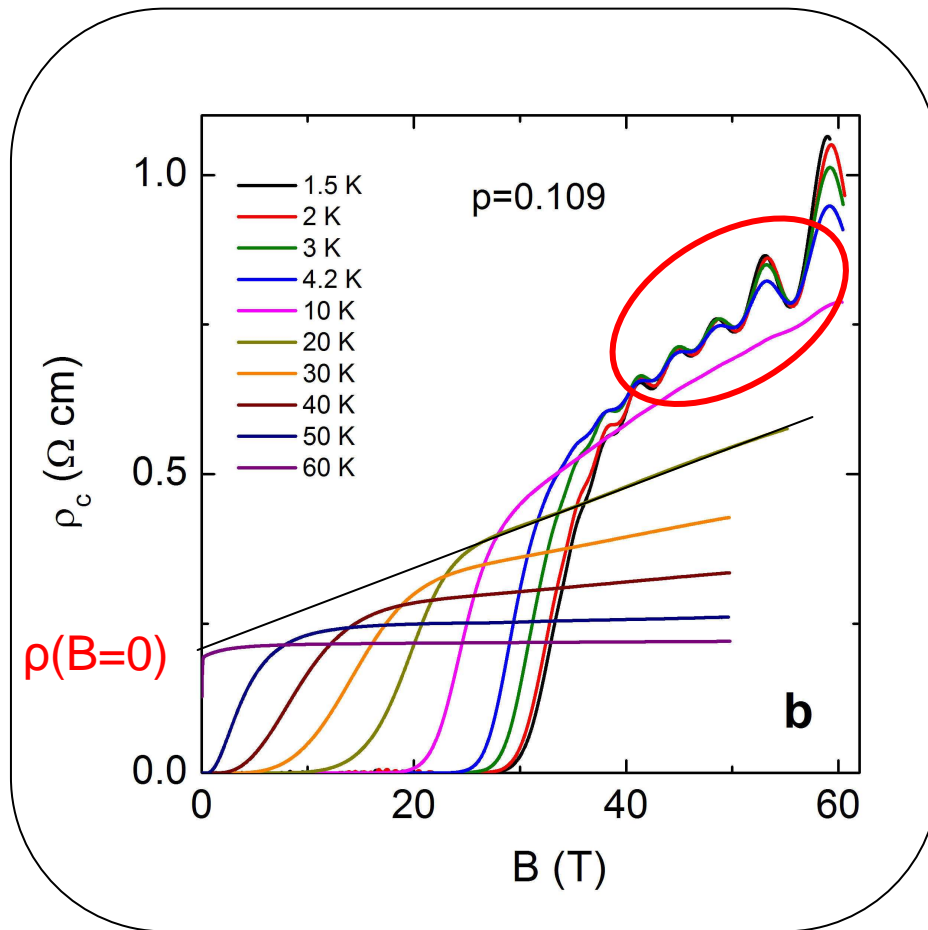
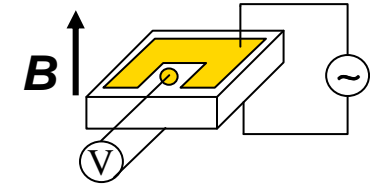
Comportement à plus basse température ?

Mesures sous champ pour détruire la supra

c-axis magnetoresistance in underdoped YBCO

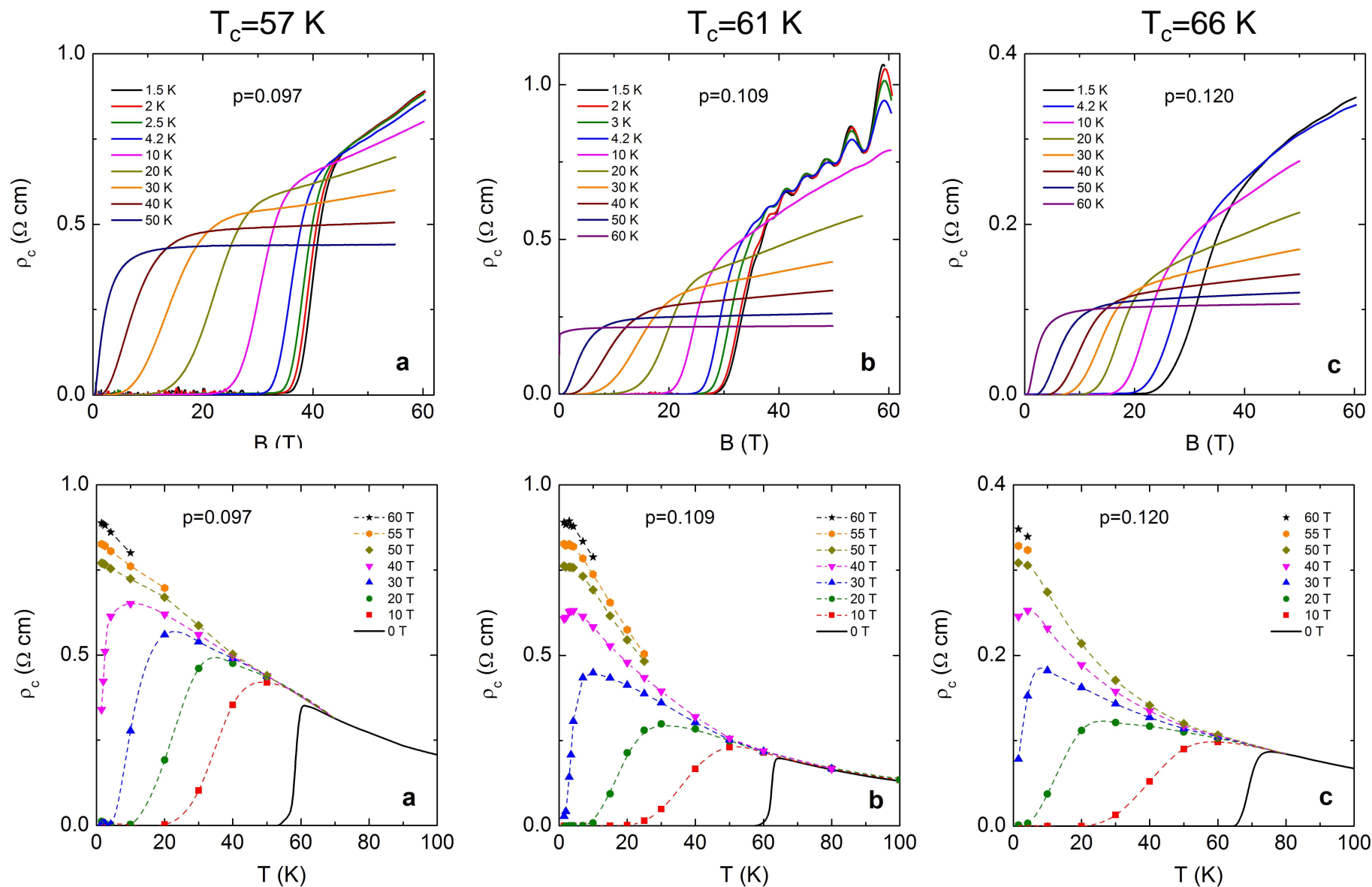
Sous-dopé
 $\text{YBa}_2\text{Cu}_3\text{O}_{6.5}$

$T_c = 61 \text{ K}$; $p = 0.109$



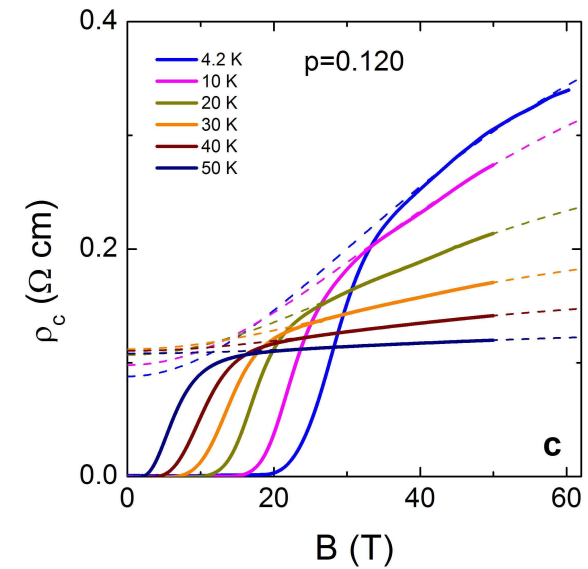
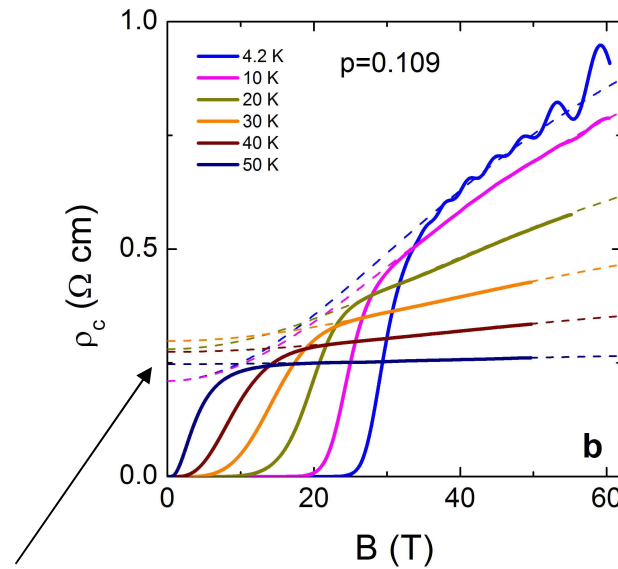
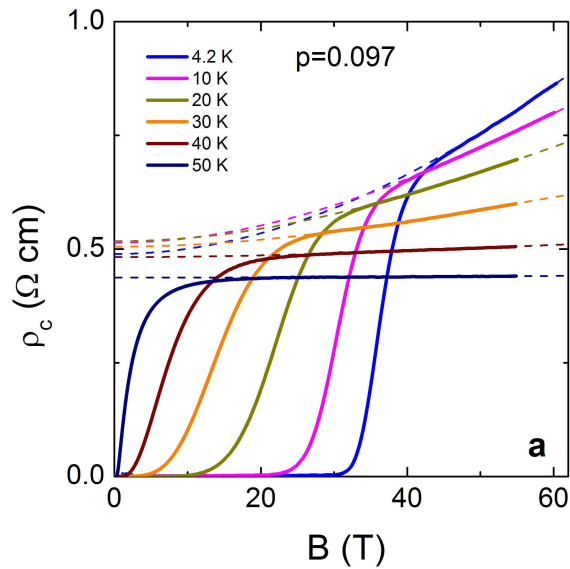
Saturation à basse T !

c-axis magnetoresistance in underdoped YBCO



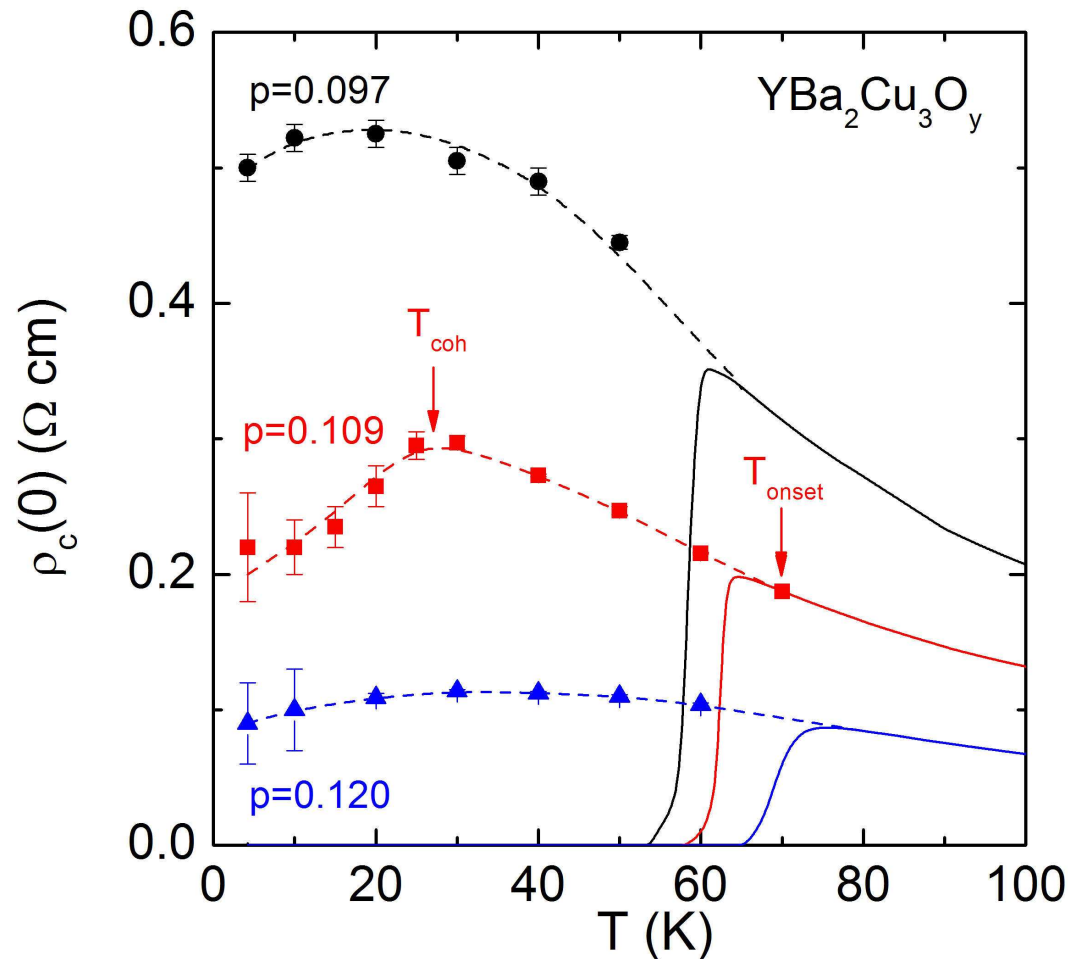
Extrapolation of the in-field resistivity to $B=0$

Two-band model:
$$\rho(B) = \frac{(\mu_h + \mu_e) + \mu_h \mu_e (\mu_h R_h^2 + \mu_e R_e^2) B^2}{(\mu_h + \mu_e)^2 + \mu_h^2 \mu_e^2 (R_h + R_e)^2 B^2} = \rho_0 + \frac{\alpha B^2}{1 + \beta B^2}$$



$\rho_c(0)$: extrapolated zero-field resistivity

Temperature dependence of $\rho_c(0)$



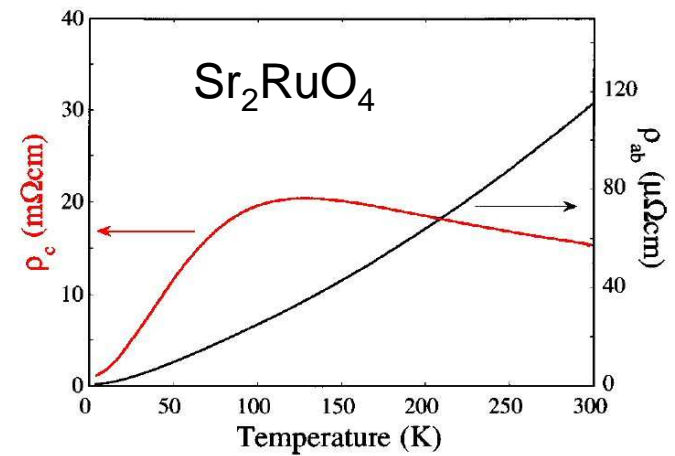
3D Fermi Surface in underdoped YBCO!

Cross-over:

Incoherence \rightarrow Coherence

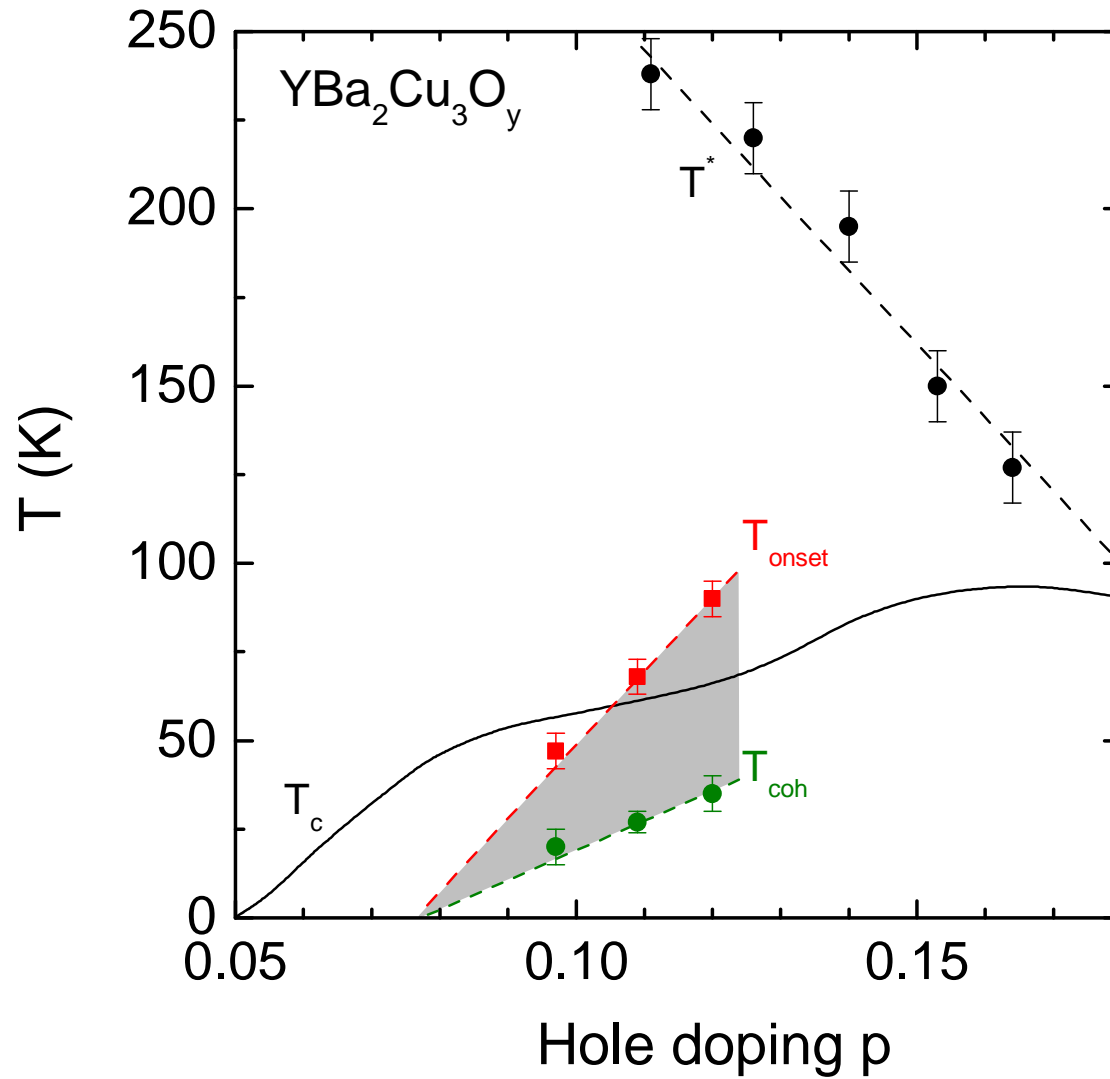
$T_{coh} = 27 \pm 5$ K for $p=0.109$

Good agreement with $t_{\perp} \sim 15$ K from QO

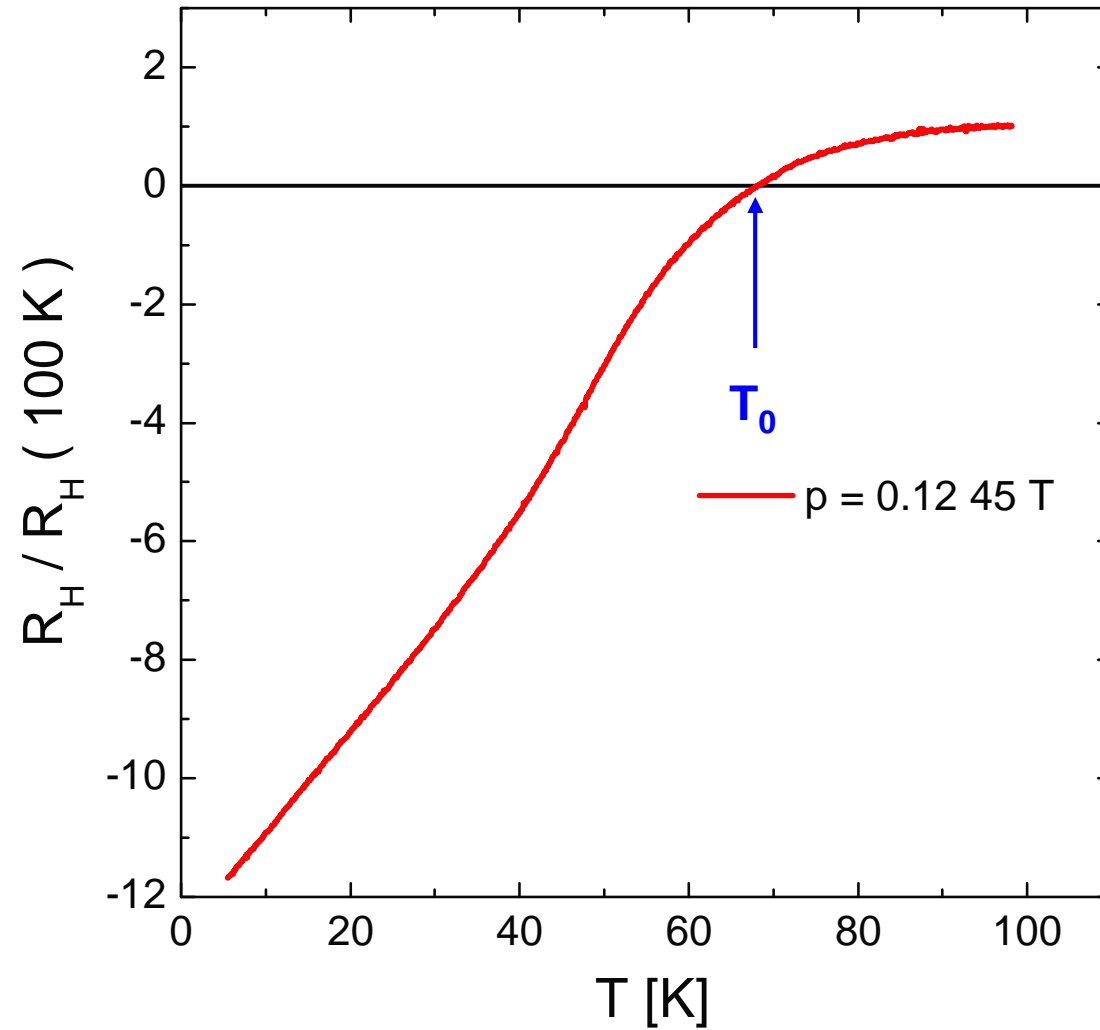


Transport cohérent lié à poche électron aux AN

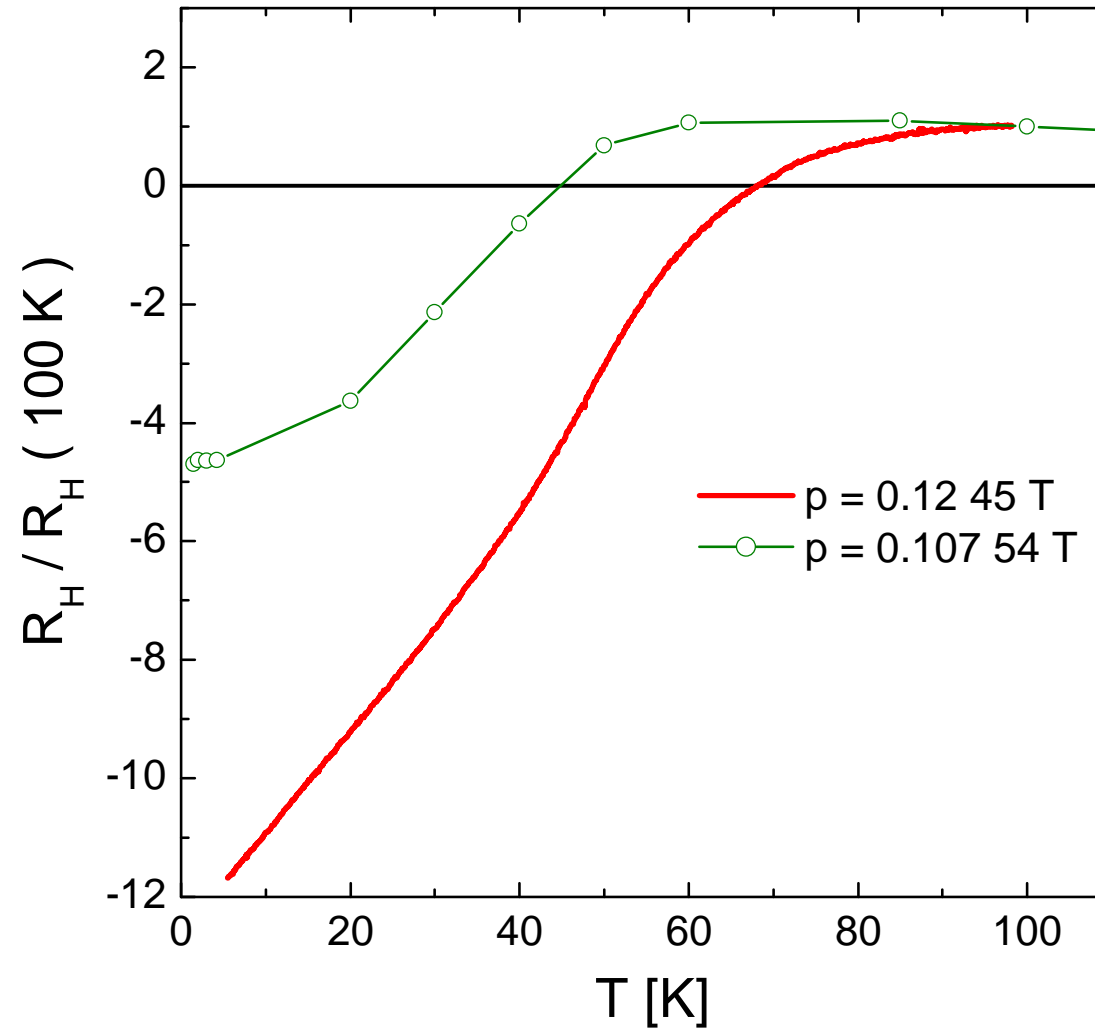
Phase diagram



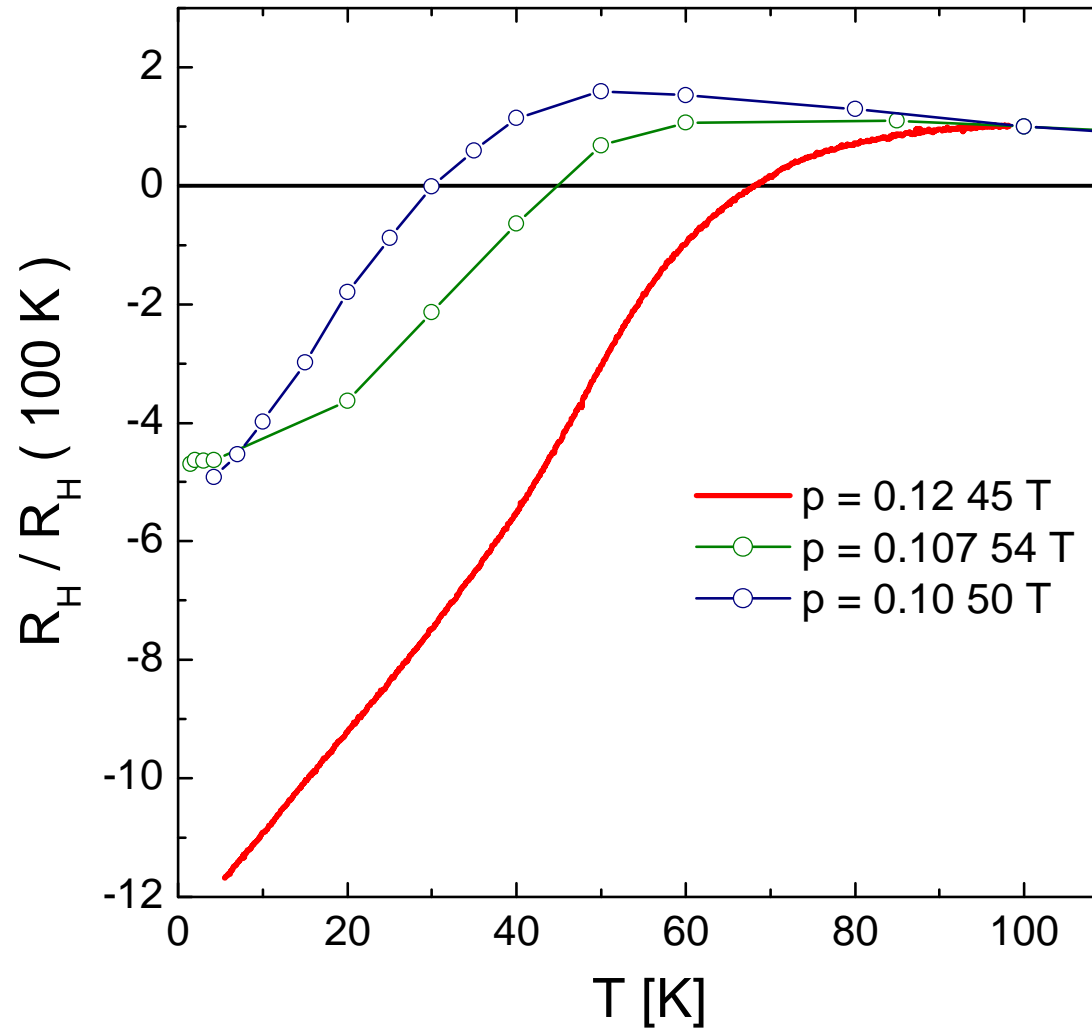
Doping dependence of the Hall effect



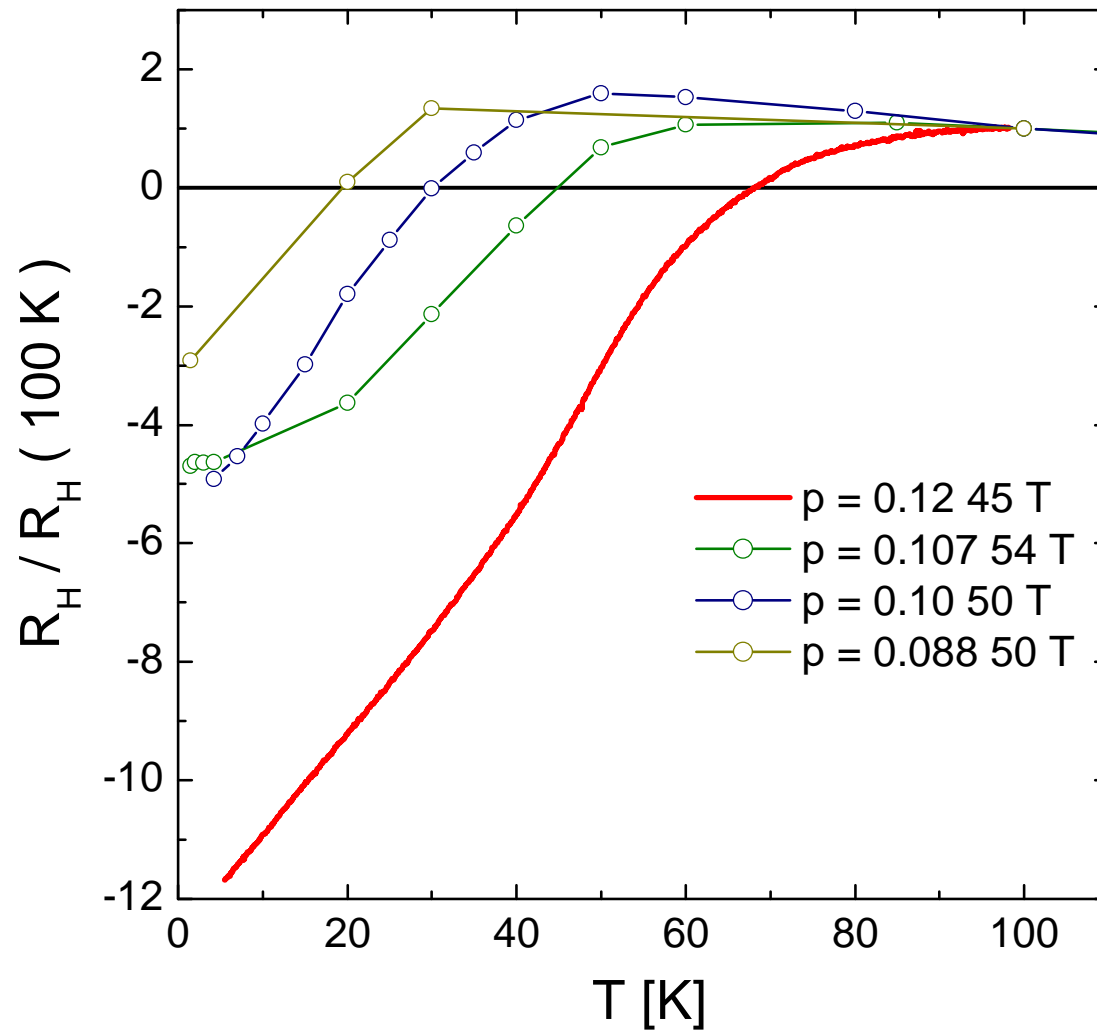
Doping dependence of the Hall effect



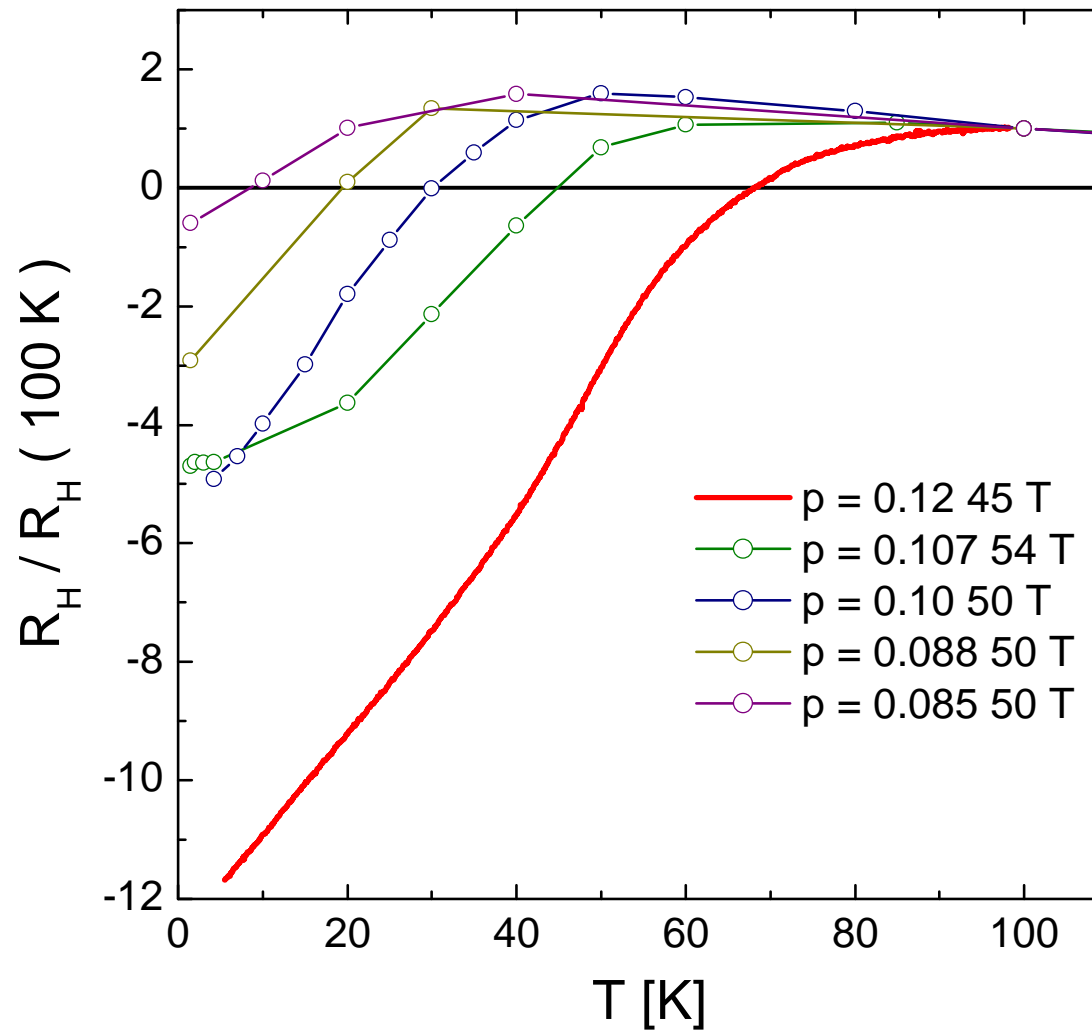
Doping dependence of the Hall effect



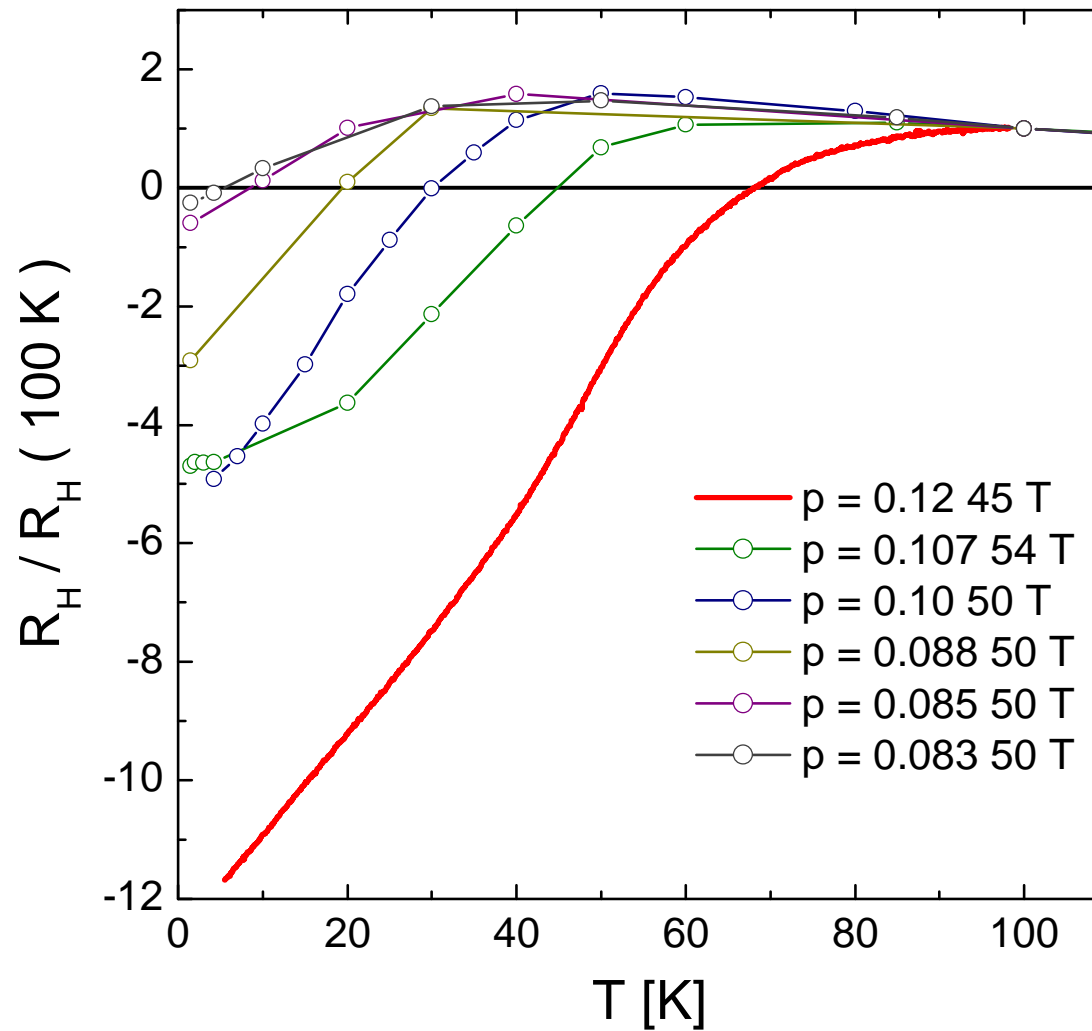
Doping dependence of the Hall effect



Doping dependence of the Hall effect

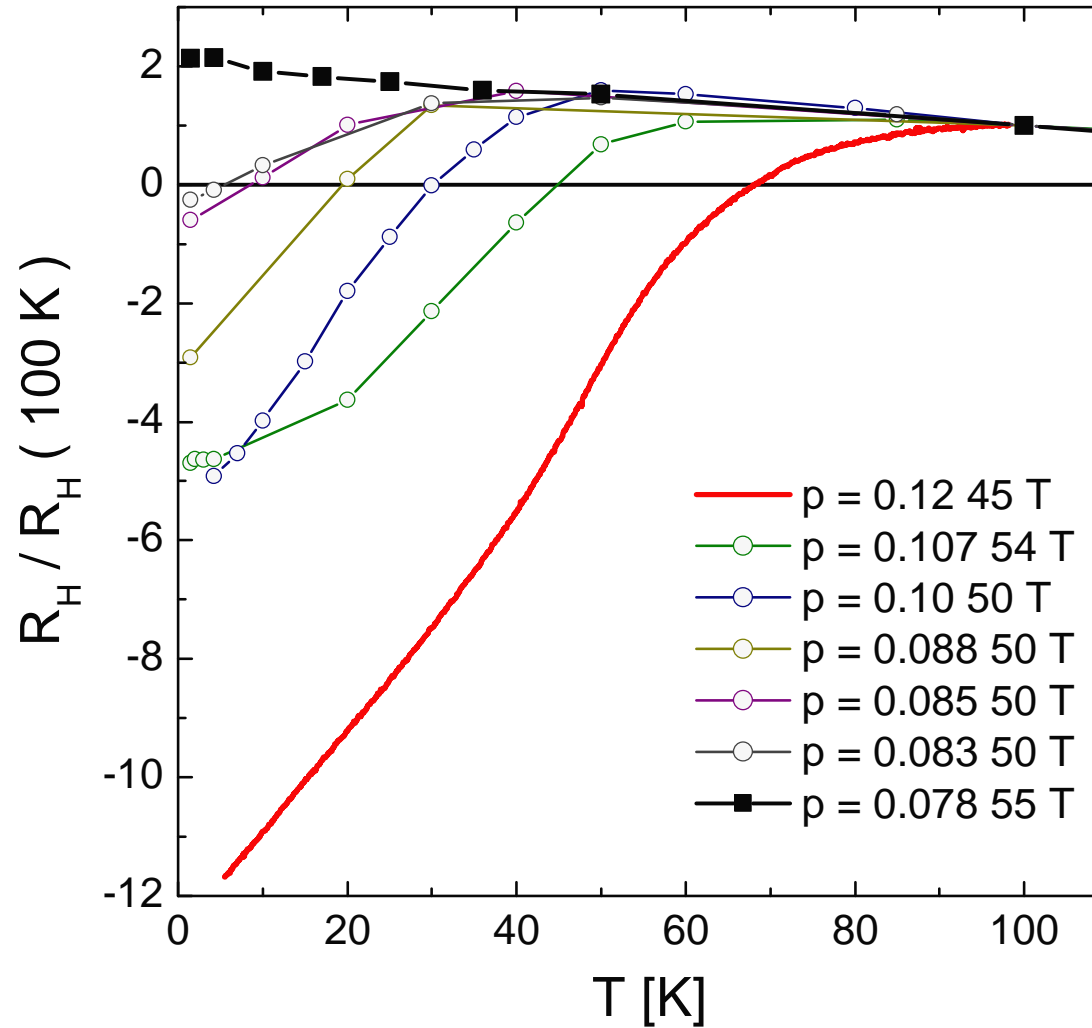


Doping dependence of the Hall effect

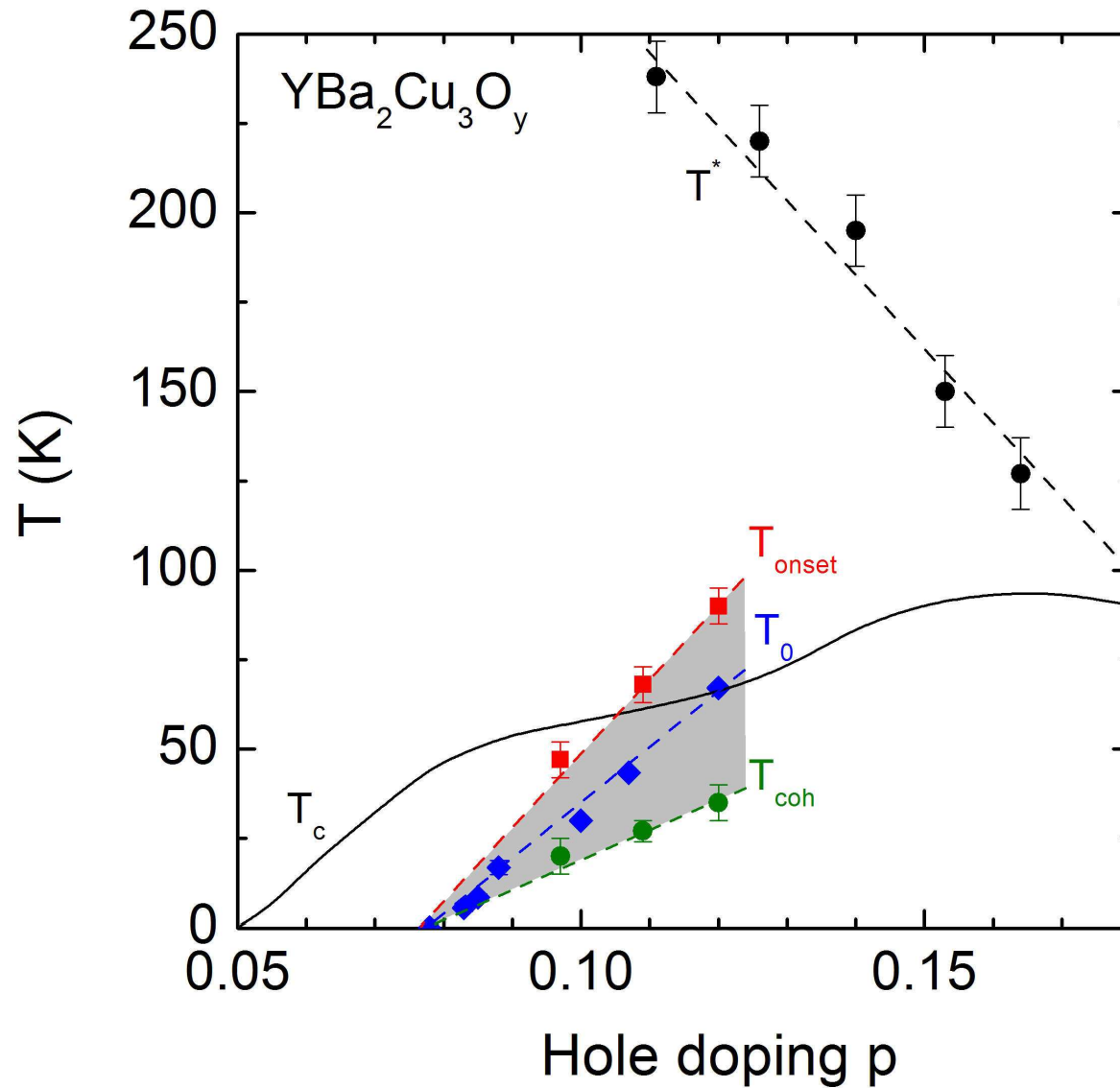


Doping dependence of the Hall effect

No sign change below $p \sim 0.08$



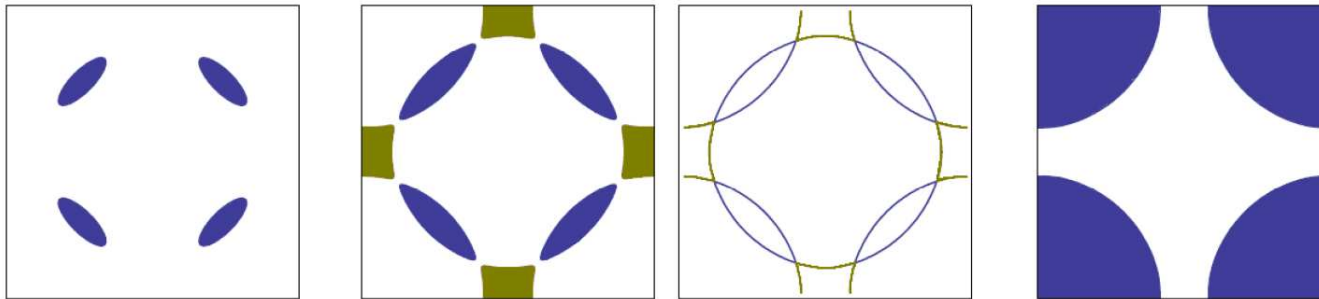
Phase diagram



Disappearance of the electron pocket

Lifshitz transition at $p \sim 0.08$

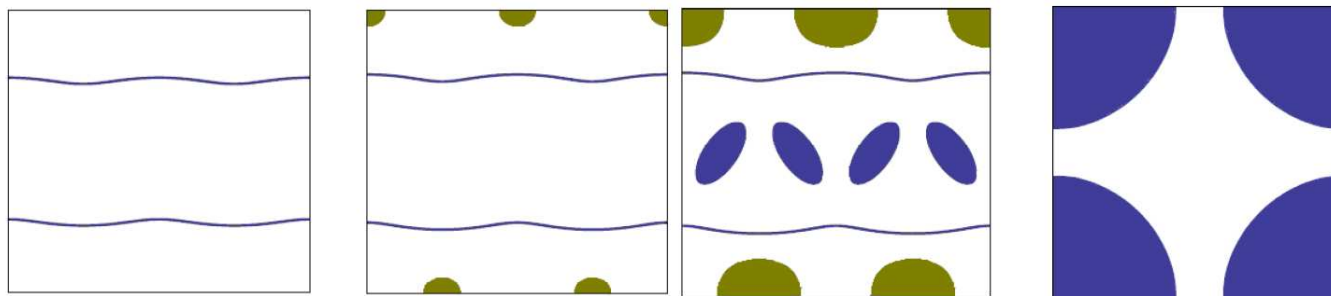
Spin density wave with $\mathbf{Q}=(\pi, \pi)$ reconstruction



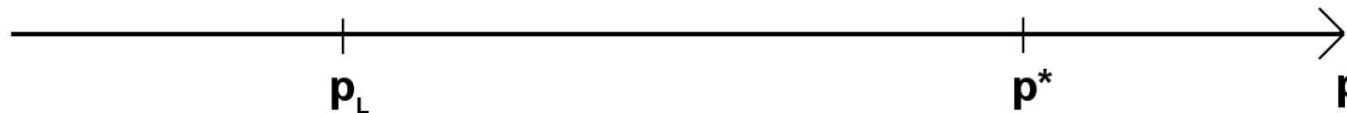
Sachdev
Chubukov...

Doping

Spin density wave with $\mathbf{Q}=(1-2\delta, 1)\pi/a$ reconstruction



Norman
LeBoeuf



Link with ARPES

What is the link between:

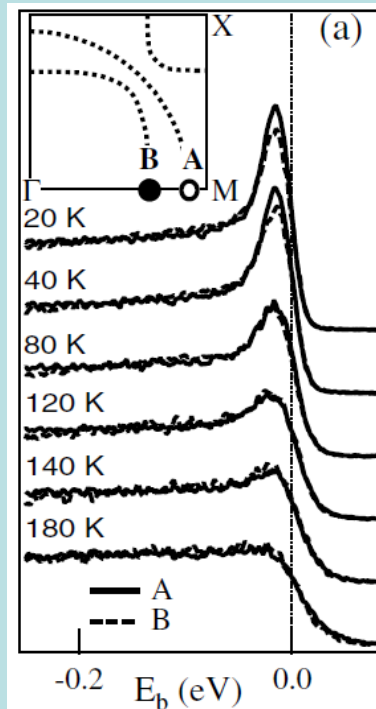
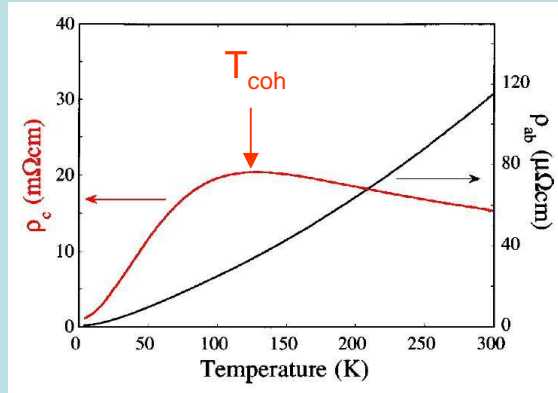
T_{coh} (from c-axis transport)

and

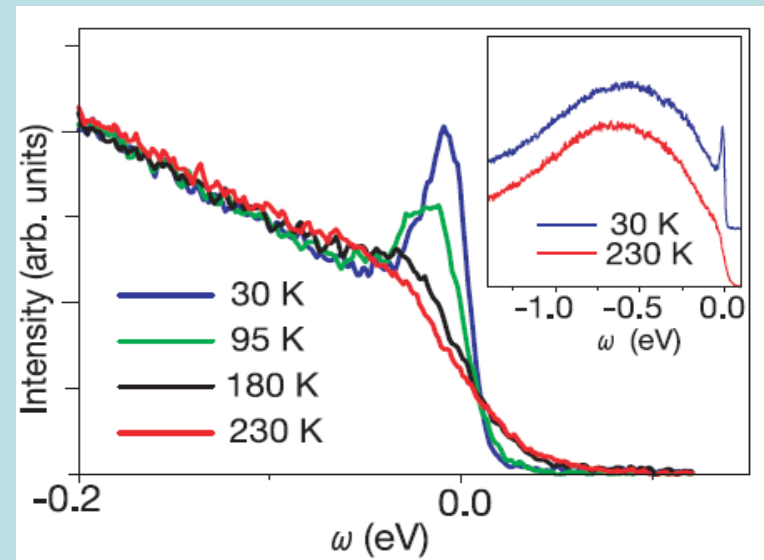
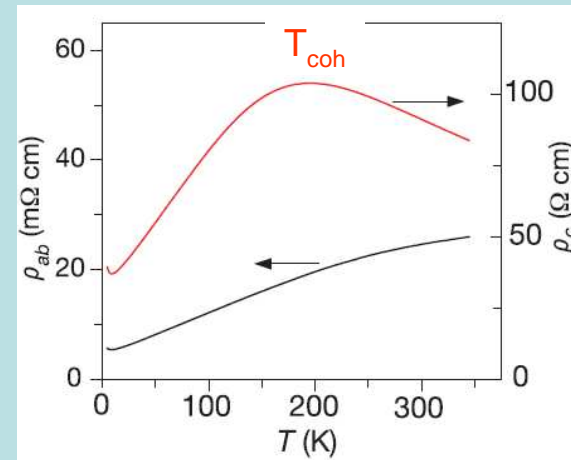
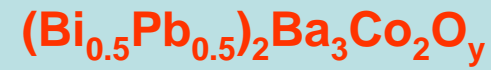
the quasiparticle peak seen by ARPES?

⇒ Analogy with other Q2D strongly correlated electron systems

Link with ARPES

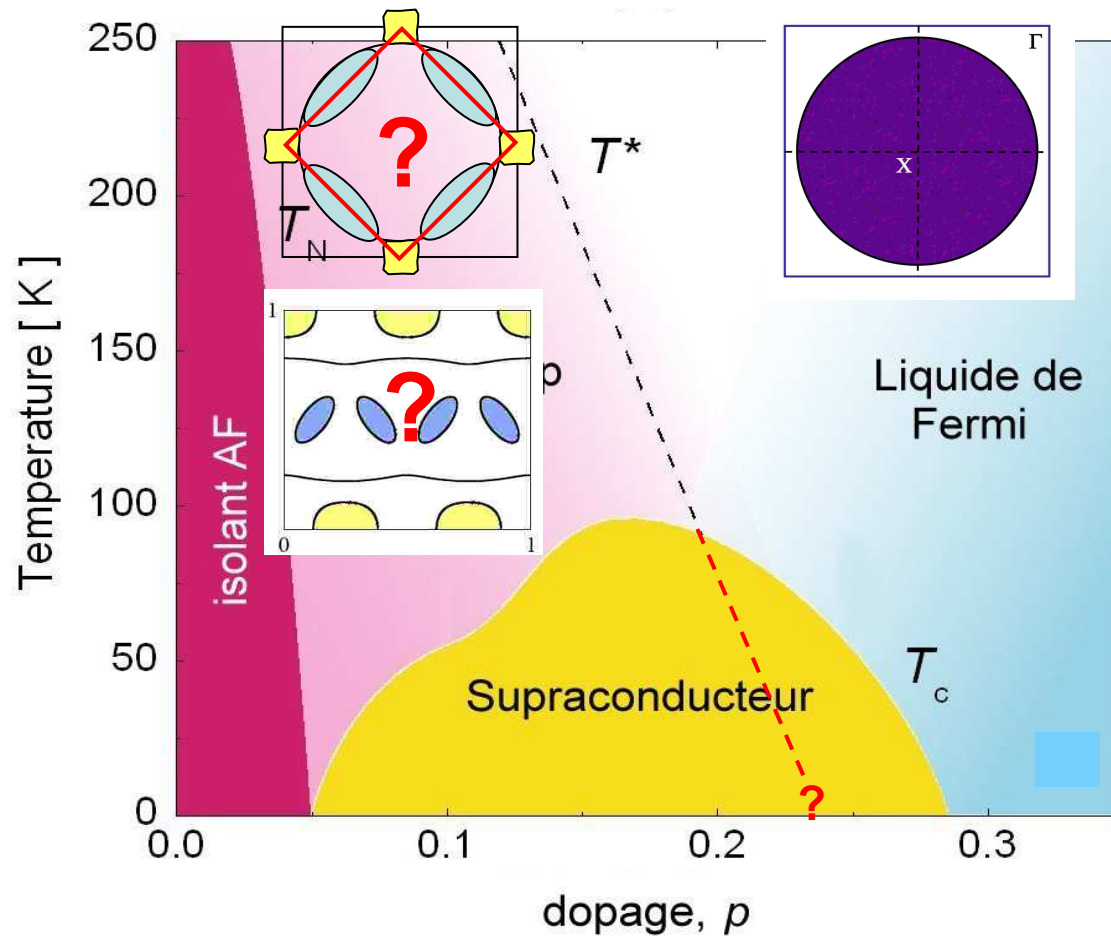


S.-C. Wang et al, PRL'04



T. Valla et al, Nature'02

Supraconducteurs à haute T_c : Conclusion

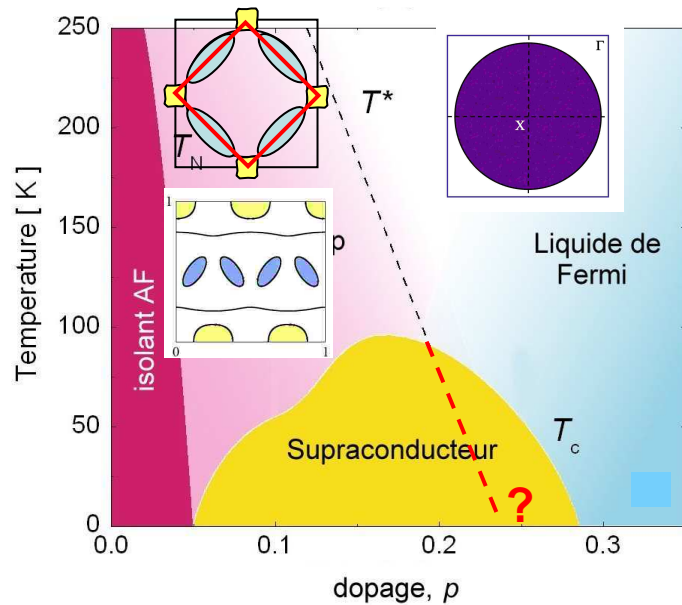


Reconstruction de la Surface de Fermi : Poche d'électron aux anti-noeuds



Ordre en compétition avec la supra
Nature du paramètre d'ordre ? Point quantique critique ?

Supraconducteurs à haute T_c : Perspectives



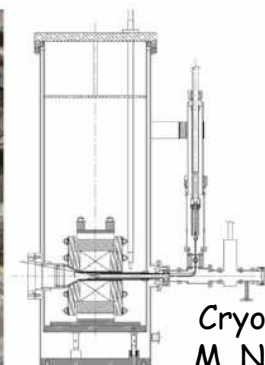
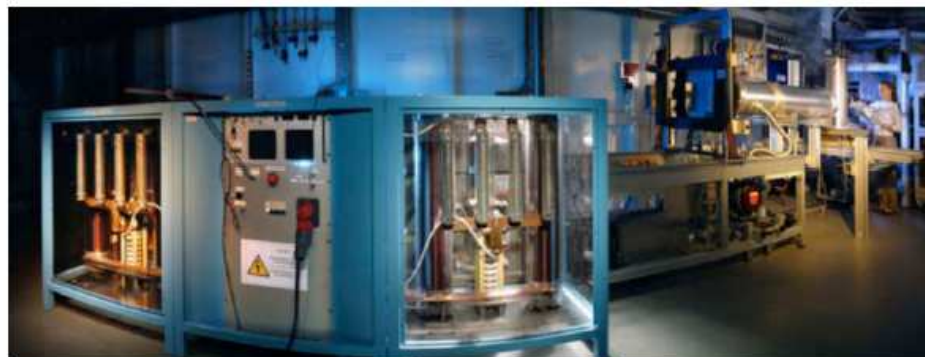
A la recherche de l'ordre perdu ...

Evolution OQ et transport avec le dopage

Vitesse et atténuation du son

RMN à fort champ : LNCMI-Grenoble
(M.H. Julien, C. Berthier ...)

Diffraction de rayons X et de neutrons en champs pulsés
ESRF/ILL/LNCMI-T (F. Duc, P. Frings)



Cryogénie :
M. Nardone

MERCI de votre attention

LNCMI-Toulouse



Champ pulsé :
60-70 T (80 T)
0.5-0.2 s (20ms)
14 MJ
+ MegaGauss
(>100T, 5 μ s)

LNCMI-Grenoble



Champ statique : 35 T / 24 MW