Thermodynamic phase diagram under high magnetic fields in underdoped $YBa_2Cu_3O_{6.54}$ single crystals

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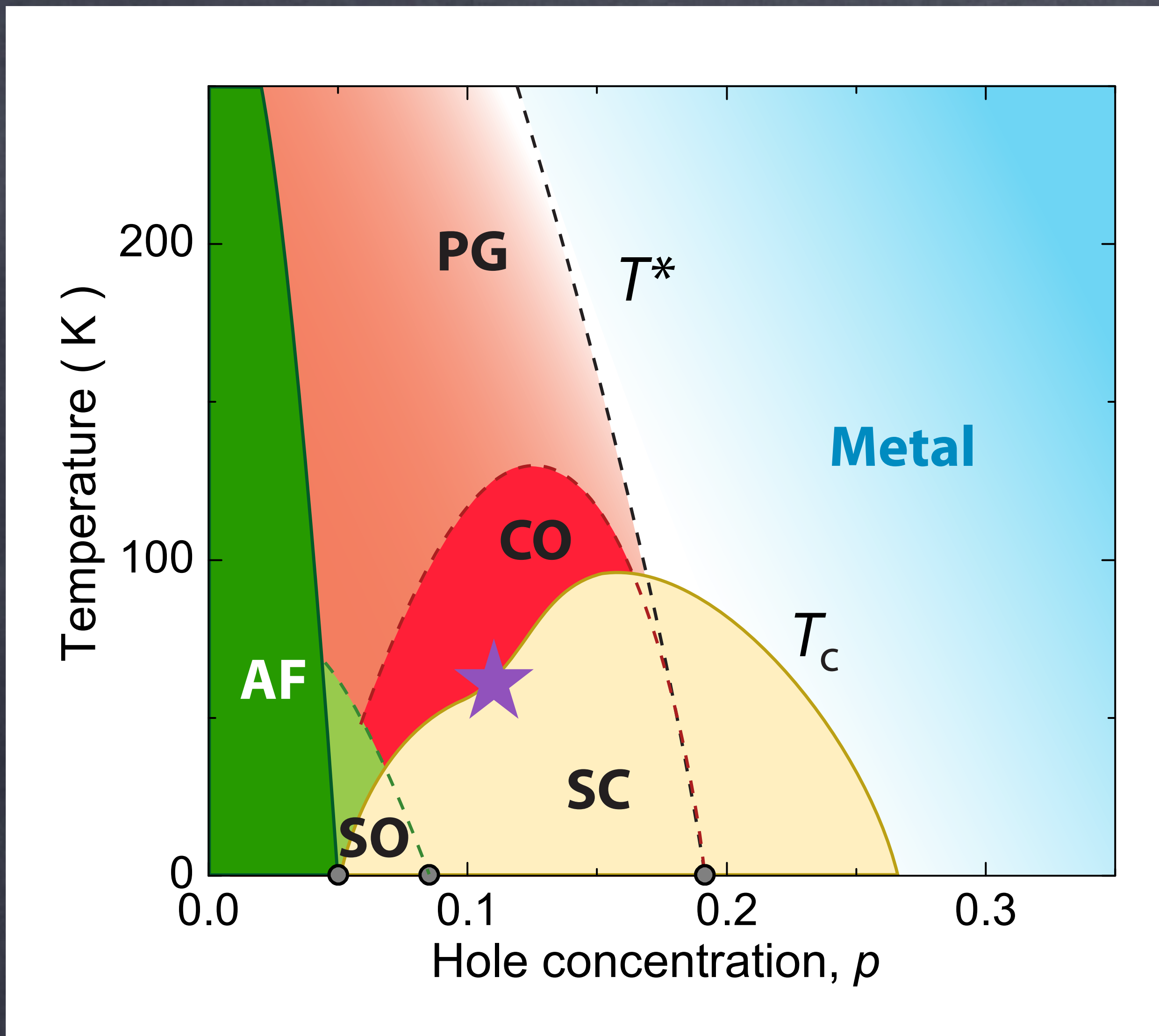
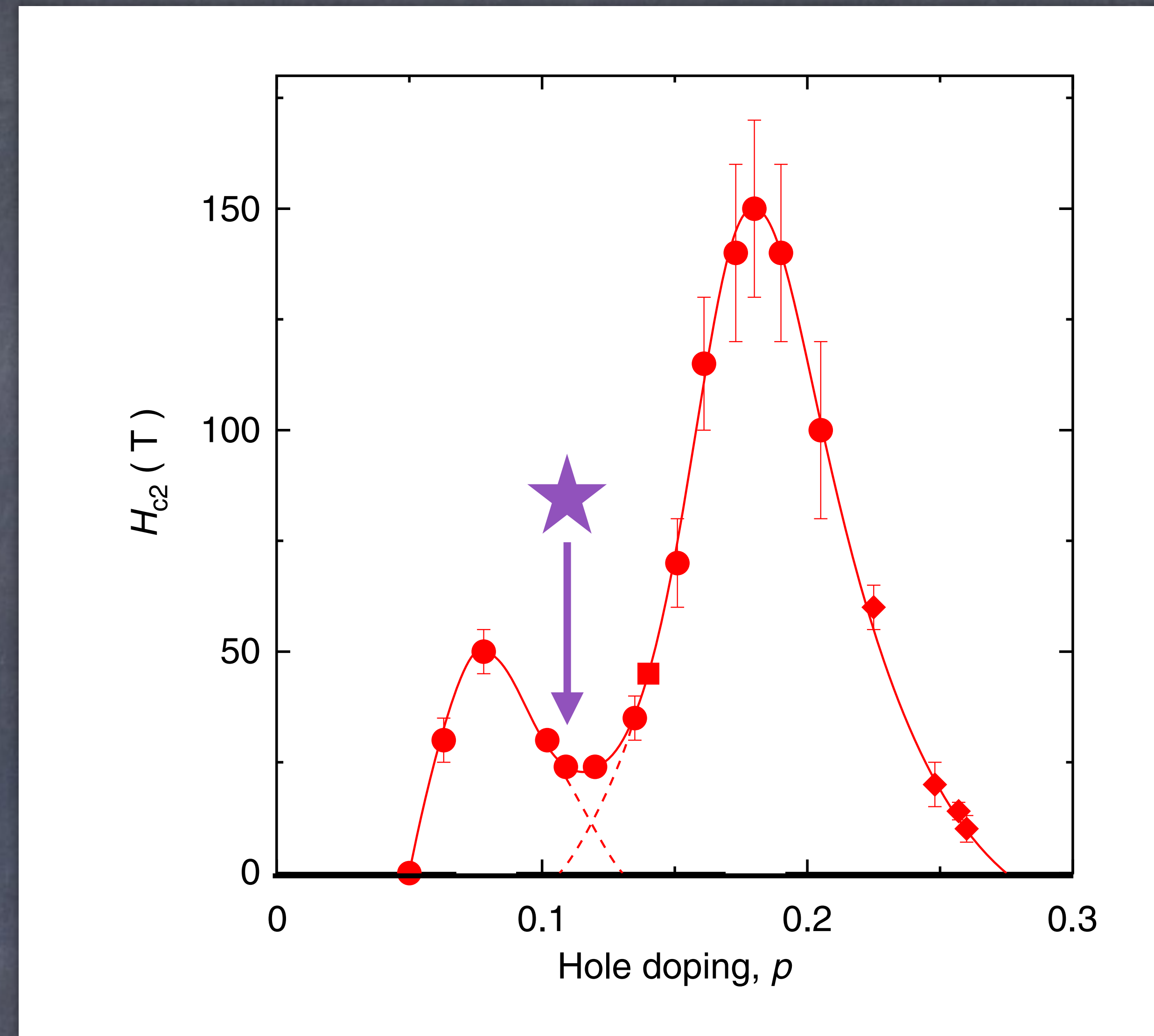
Group of Louis Taillefer, University of Sherbrooke
+ Bastien Michon («co-tutelle» PhD student)

for further details see C.Marcenat et al. Nature Com. August 21, 2015



Courtesy N.Doiron-Leyraud, Univ. of Sherbrooke



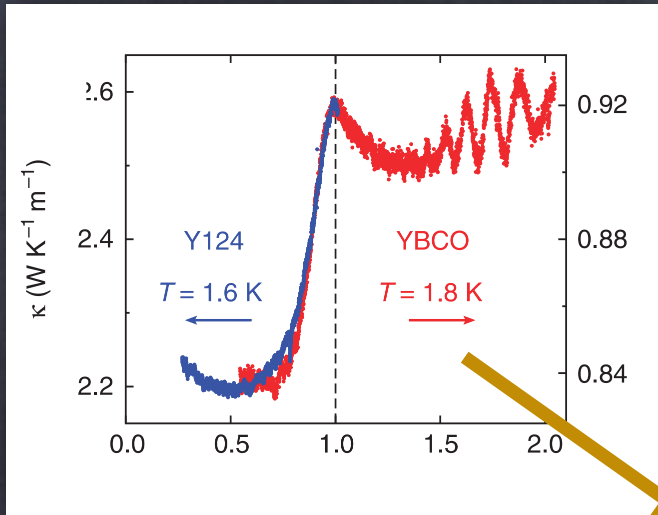
G.Grissonnanche et al. Nature Com. 2014

underdoped - YBaCuO ORTHO-II (p=0.11)

Strong reduction of **$H_{c2}(0)$ ~ 25T**

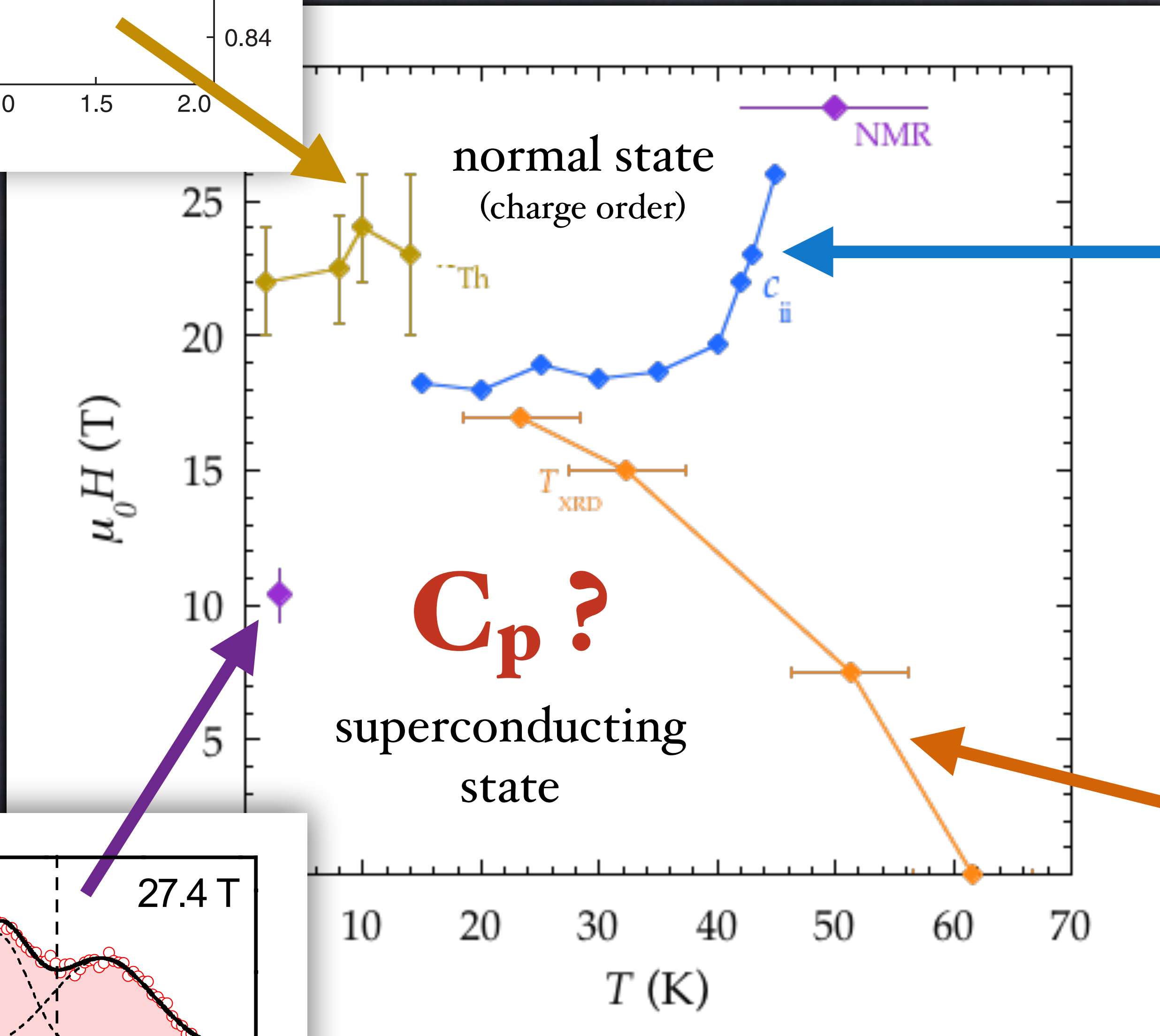
possibility to study the entire H-T phase diagram (down to the lowest temperatures)

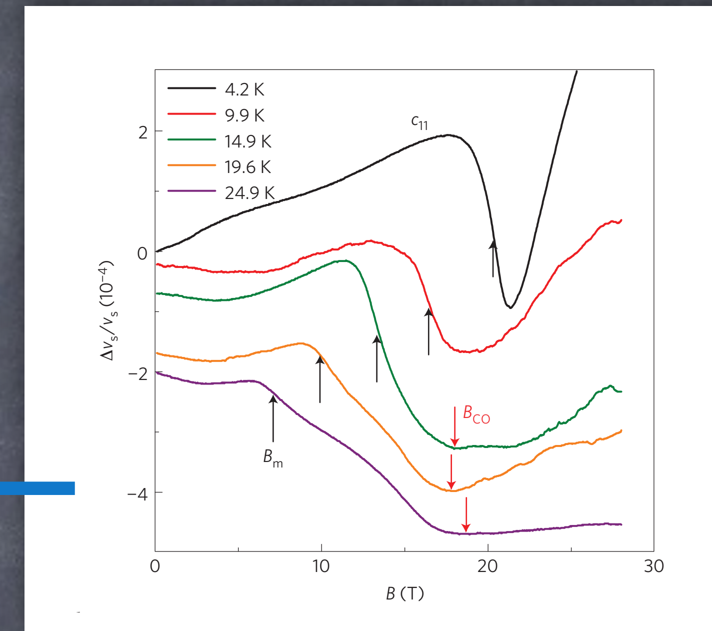
CO=charge order
SO=spin order
PG=pseudo-gap
SC=superconductor



Heat conduction

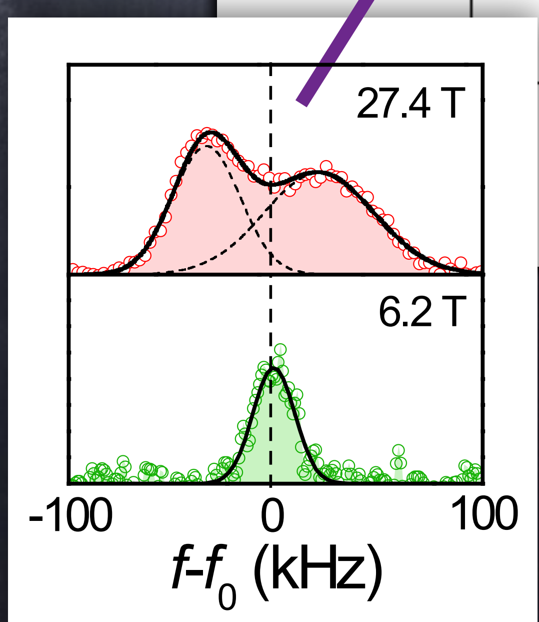
G.Grissonnanche et al. Nature Com. 2014





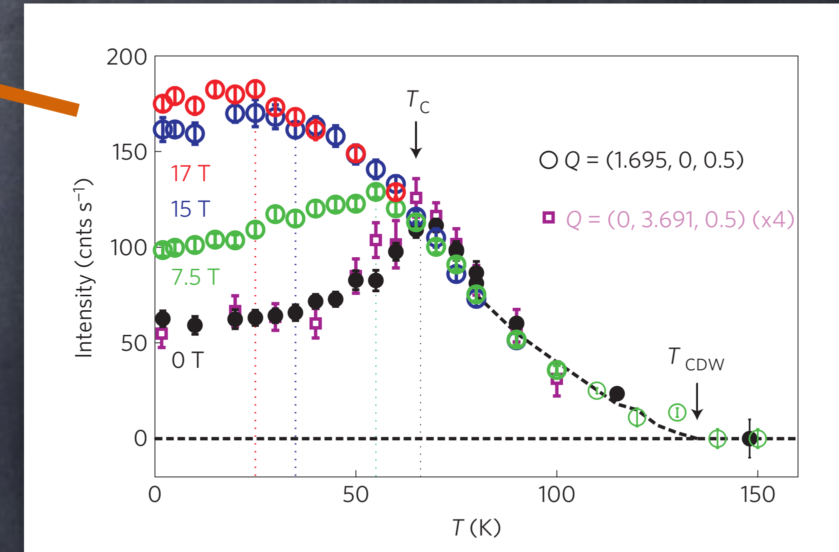
Sound velocity

D.Leboeuf et al. Nature Physics 2013



NMR

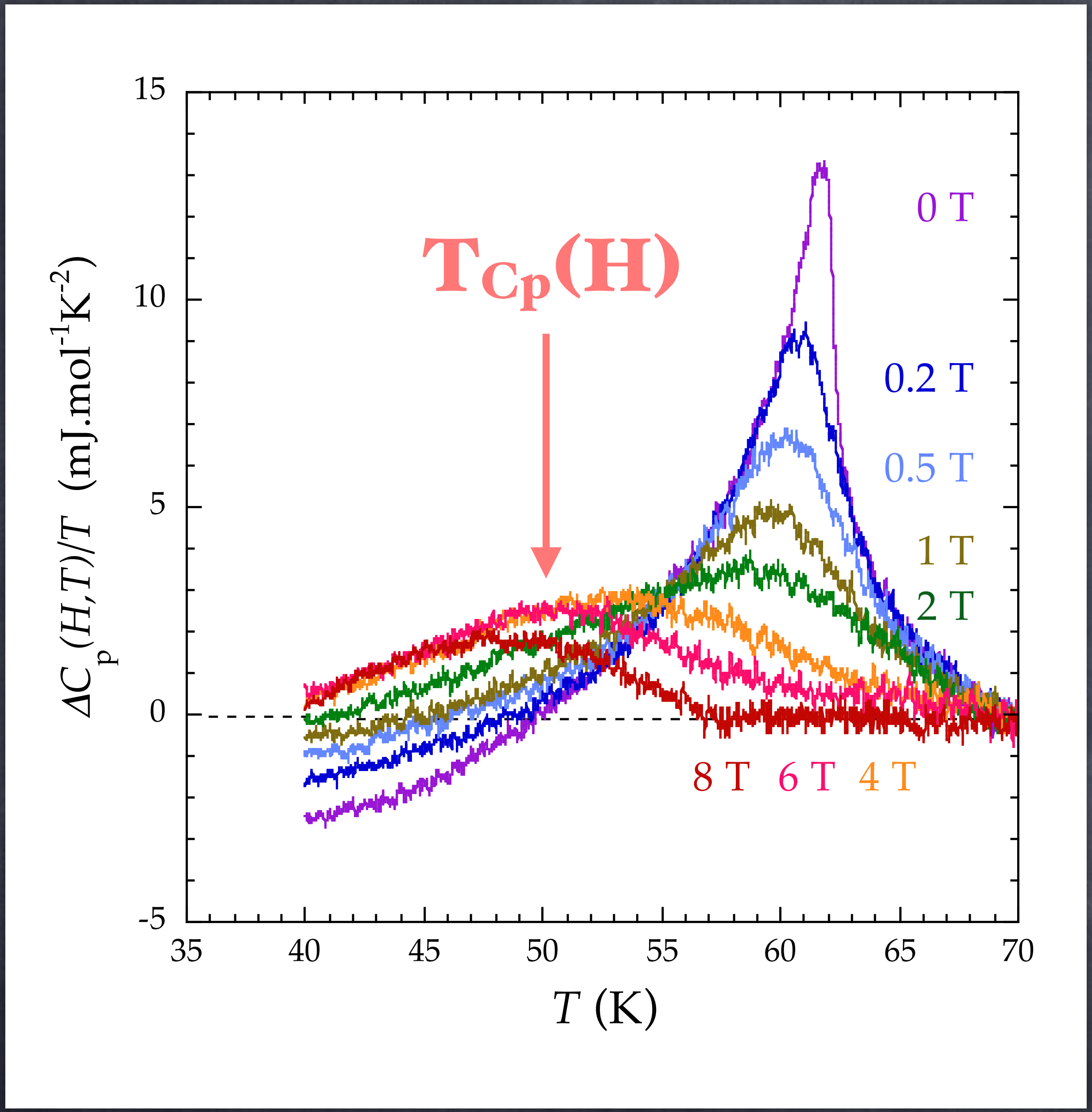
T.Wu et al. Nature 2011



X-ray diffraction (p=0.12, rescaled T)

J.Chang et al. Nature Physics 2012

Well defined specific heat anomaly around T_c ~ 62K

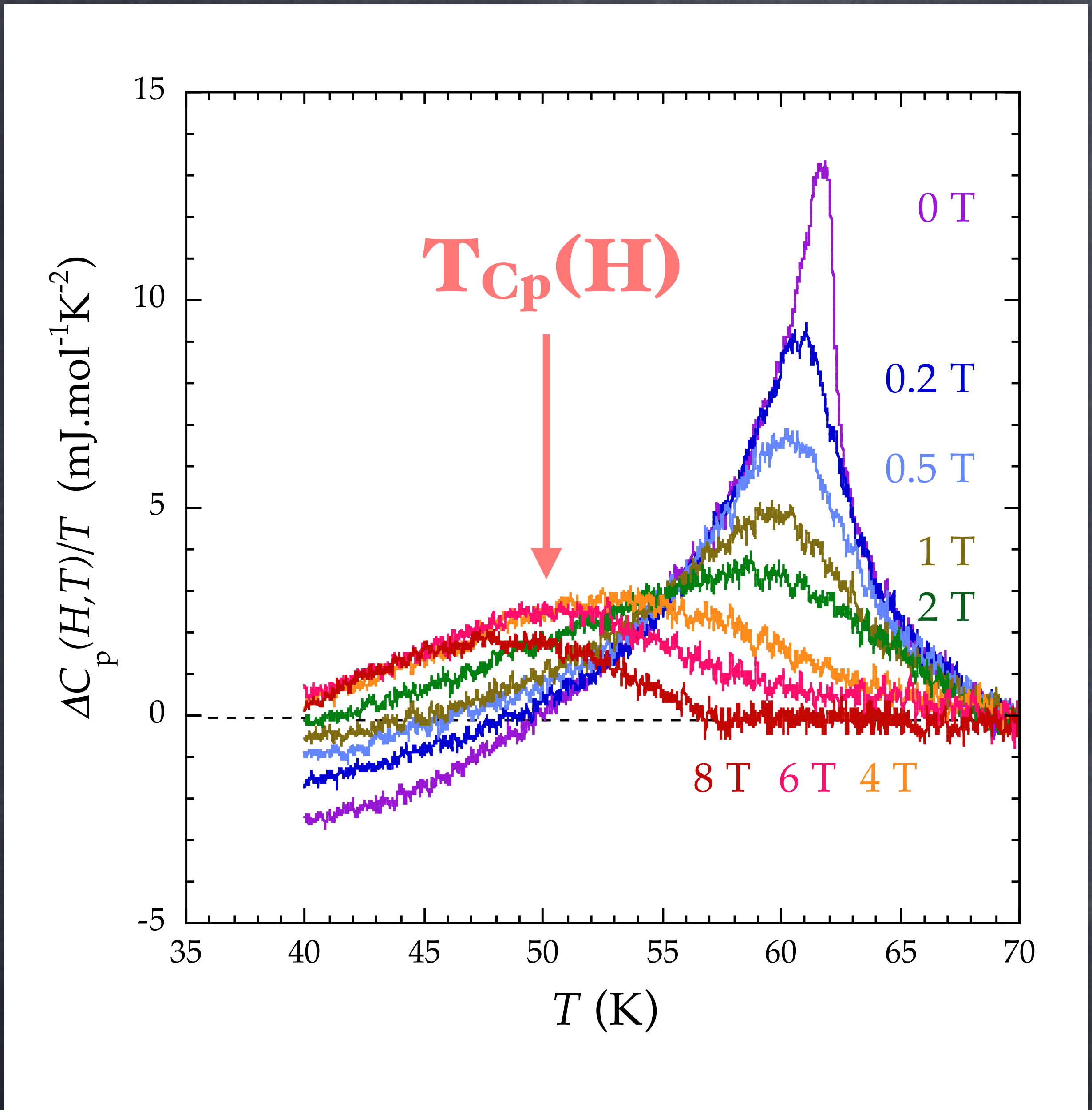


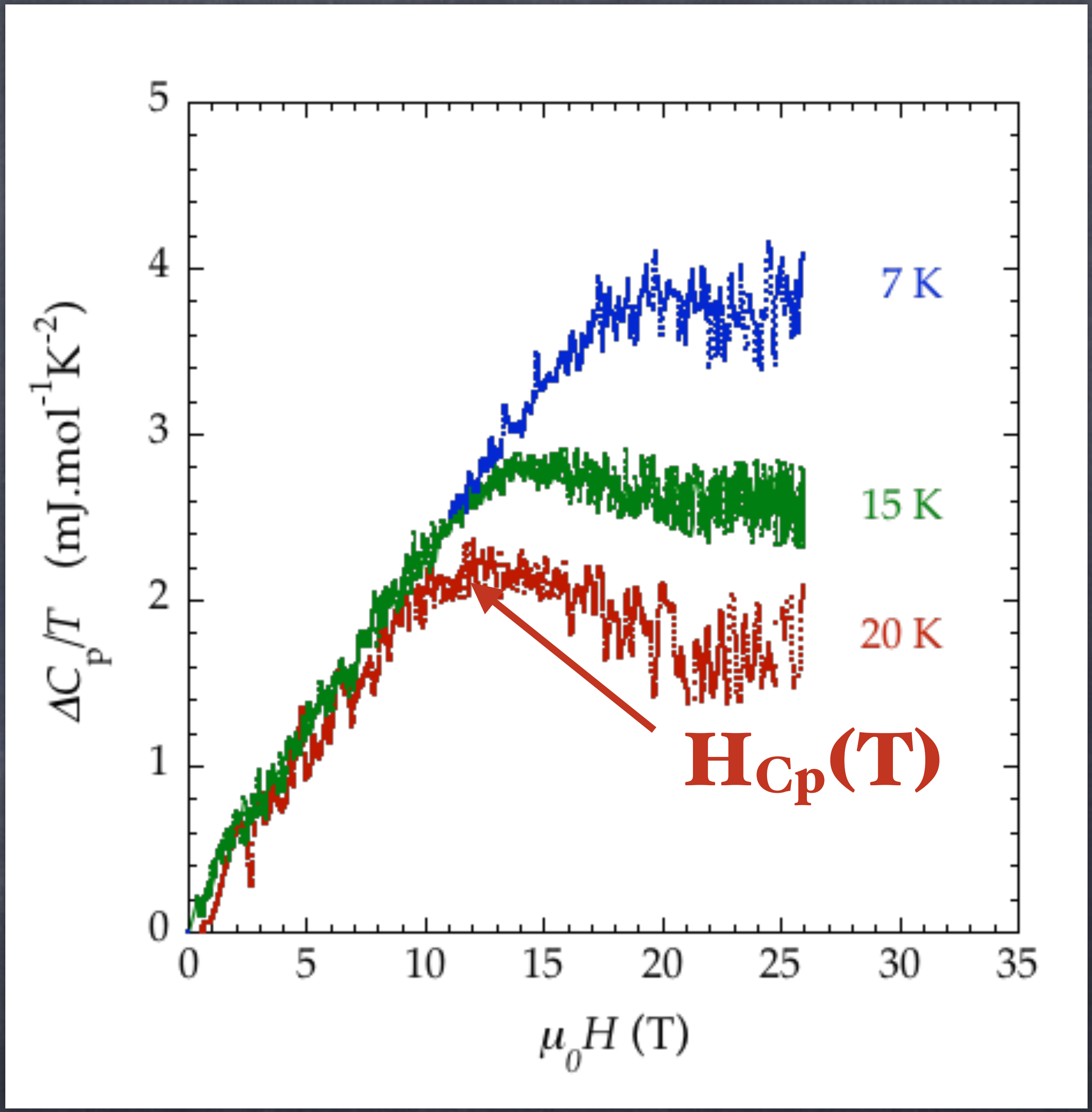
- High quality single crystals
- Not mean field
- Strong thermal fluctuations
- Critical width ~ 5-10K
- Strong curvature
- Strong reduction (for small fields)

T_{Cp} = maximum of C_p anomaly
(or inflexion point)
= T_{c2} ?

NOT a genuine phase transition (melting)

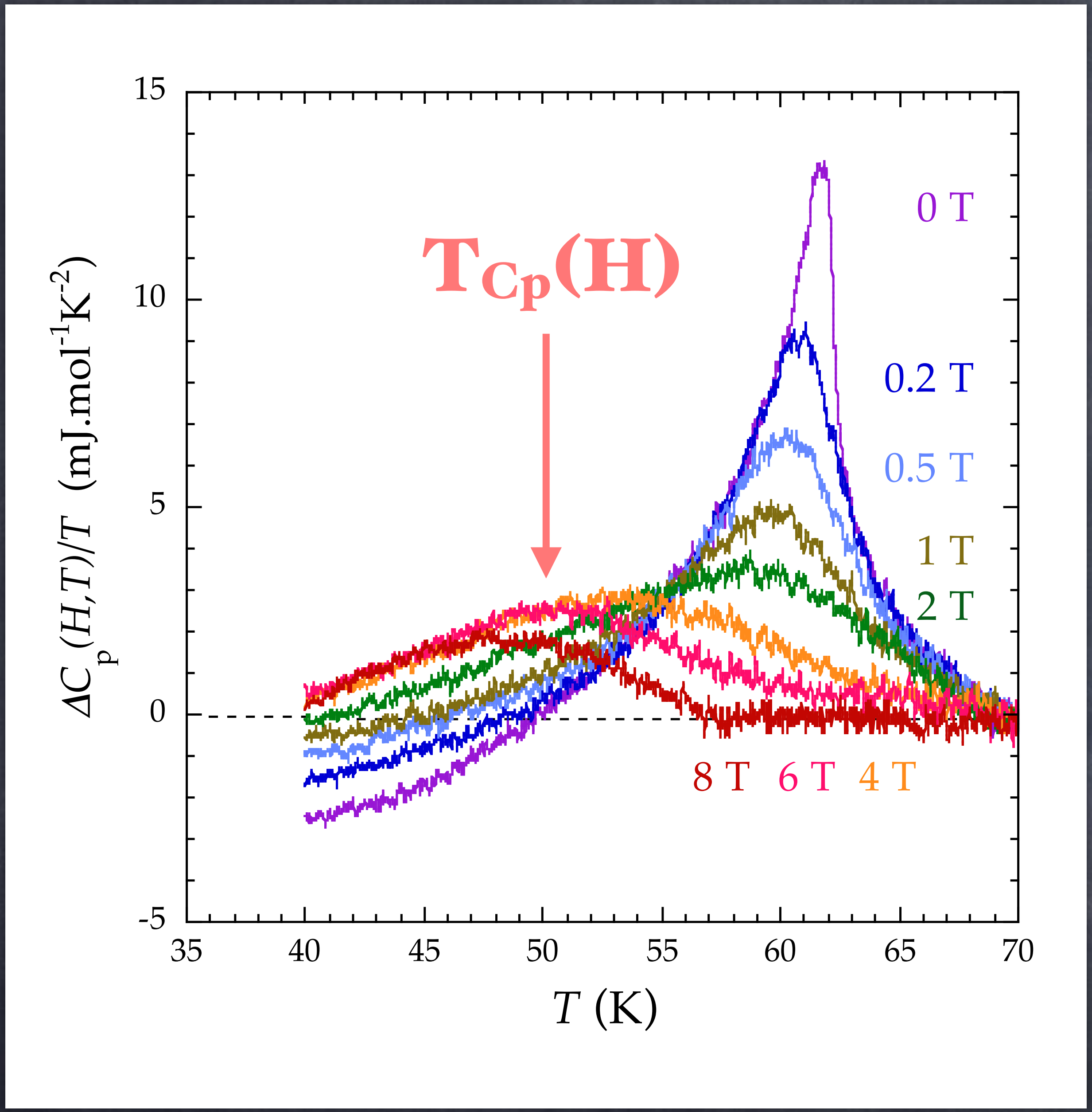
Low T ⟶ field sweeps

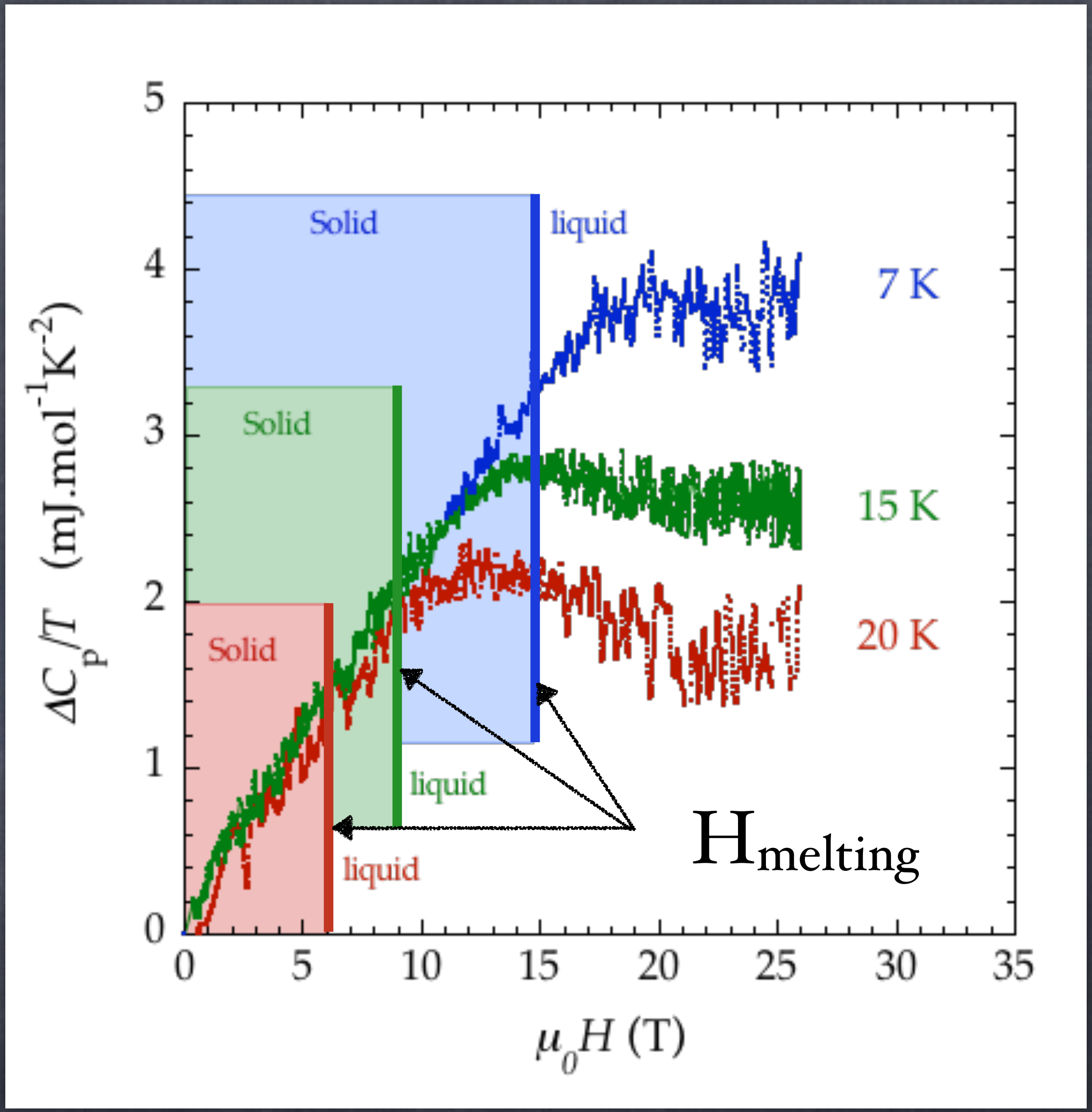




Clear saturation ⟶ normal state

Linear field dependence (possible √H at low T)

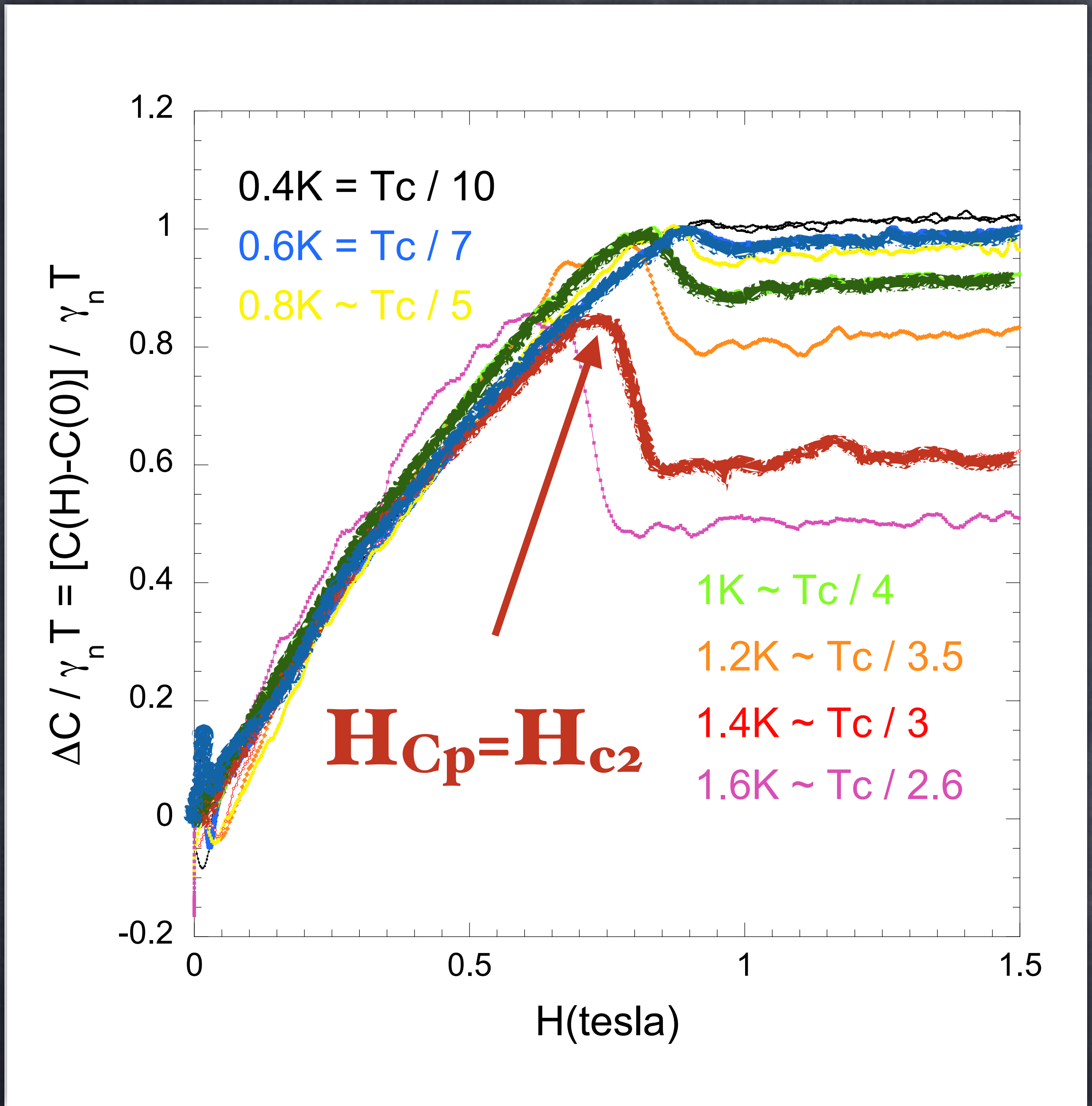


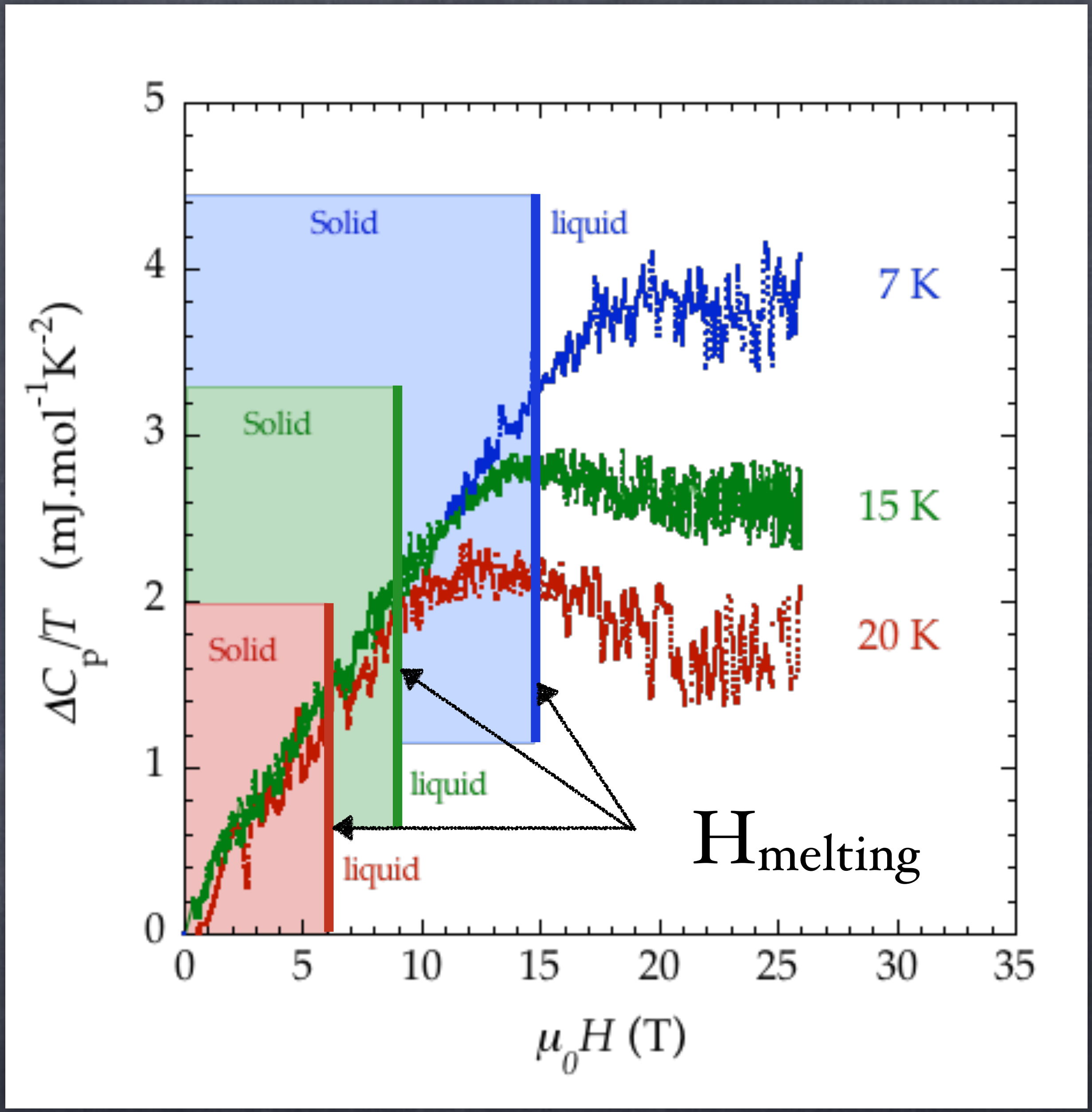


$H_{Cp} \neq H_{melting}$*

* from magnetic (Hall probe) measurements = irreversibility line

Cu_xTiSe_2





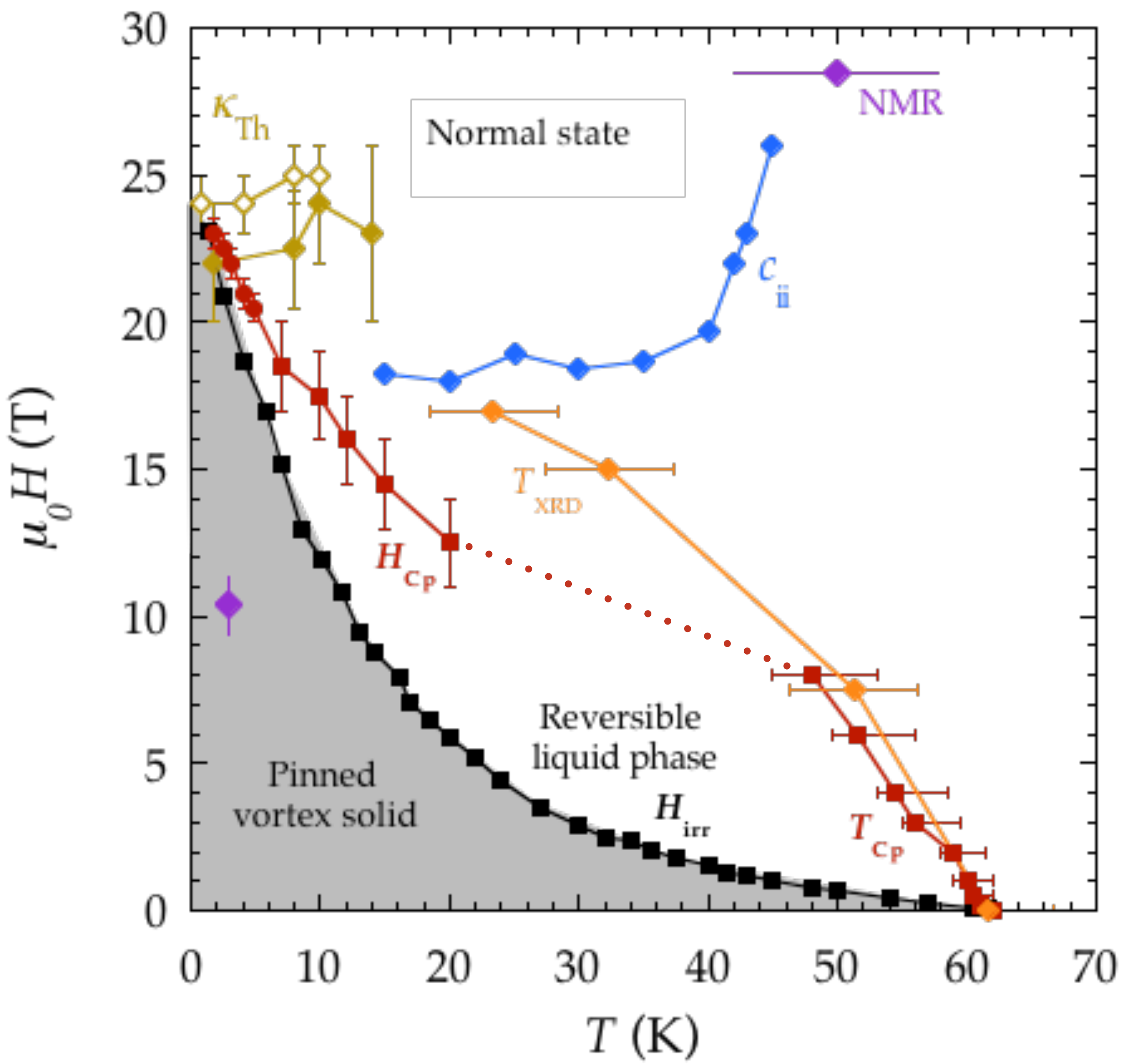
courtesy F.Levy-Bertrand

C_p jump / saturation @ H_{c2}

(no fluctuations)

$H_{Cp} \neq H_{melting}$*

* from magnetic (Hall probe) measurements = irreversibility line



- ● Double RuO chip* = thermo + heater (new)
- ■ Thermocouples + LED heating

$H_{melting}(0) = H_{Cp}(0) = H_k(0)$

$=$ **$H_{c2}(0)$**

BUT

different T dependence

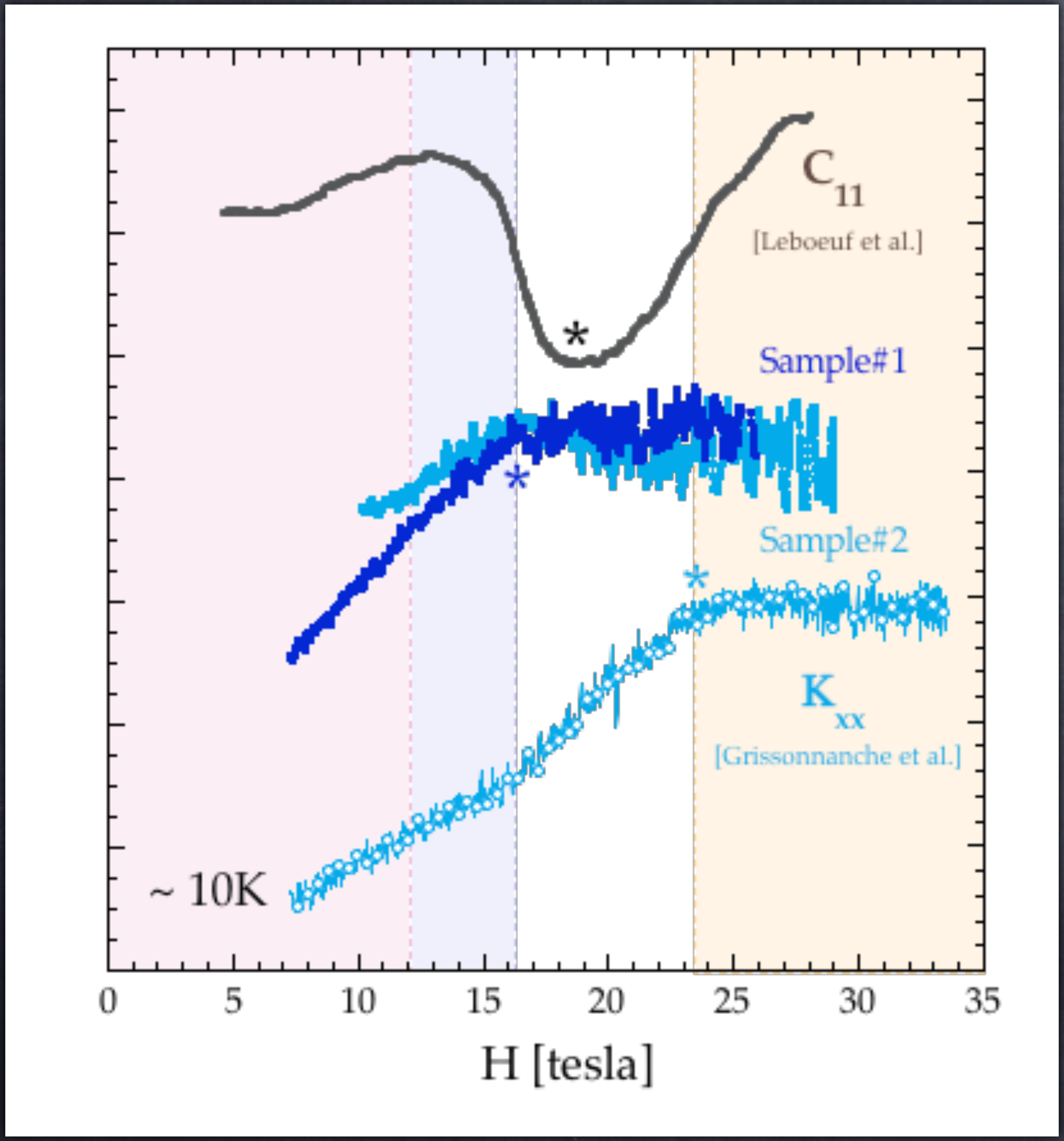
$H_{Cp} \longleftrightarrow T_{Cp}$?

Superconducting → normal or charge order transition ?

link with C_{ii} ?

* much better resolution below 10K

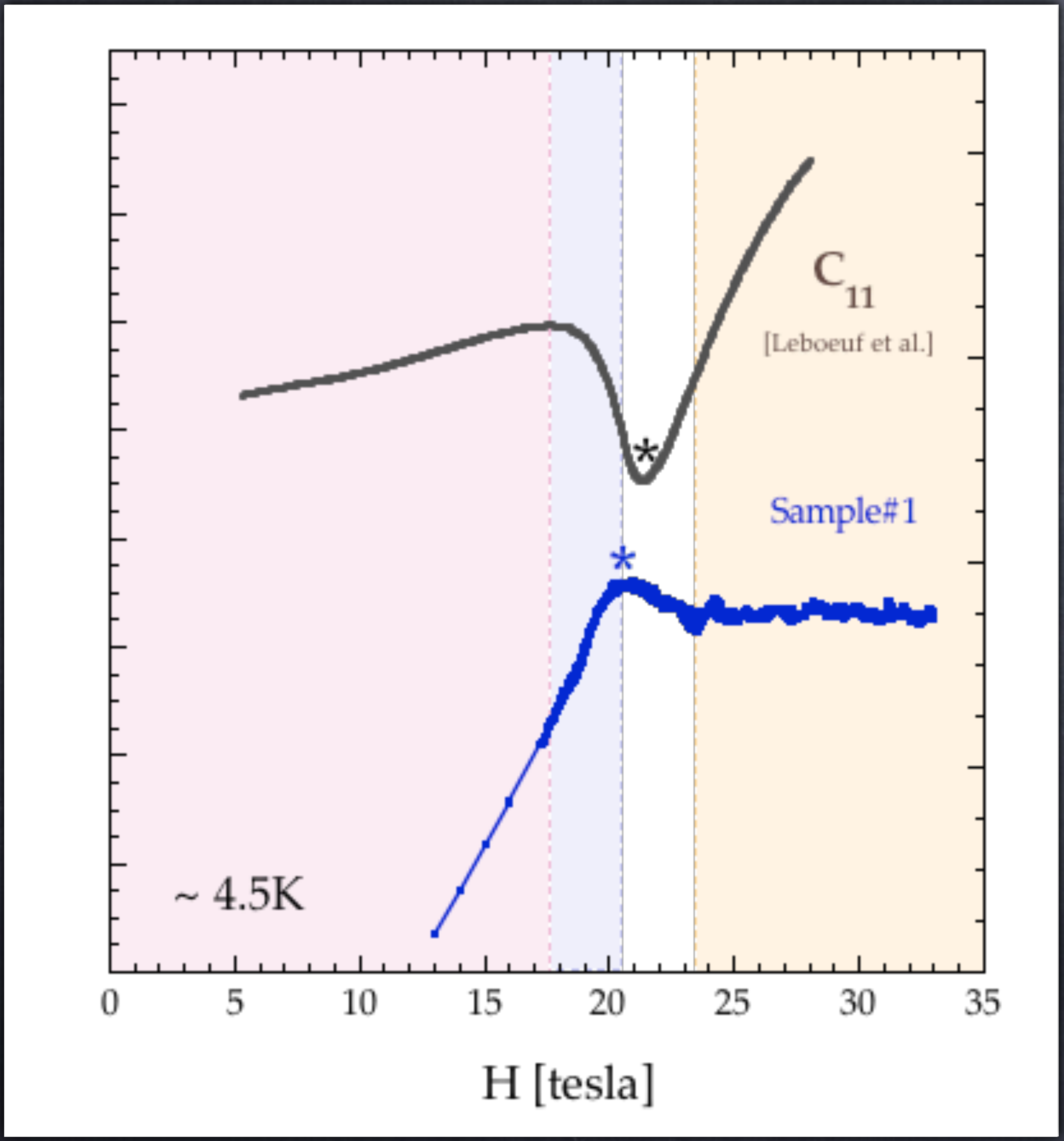
2 transitions ? or even 3 ?



or 1 large crossover ?
(with different criteria)

decreasing with T ?

2 transitions ? or even 3 ?



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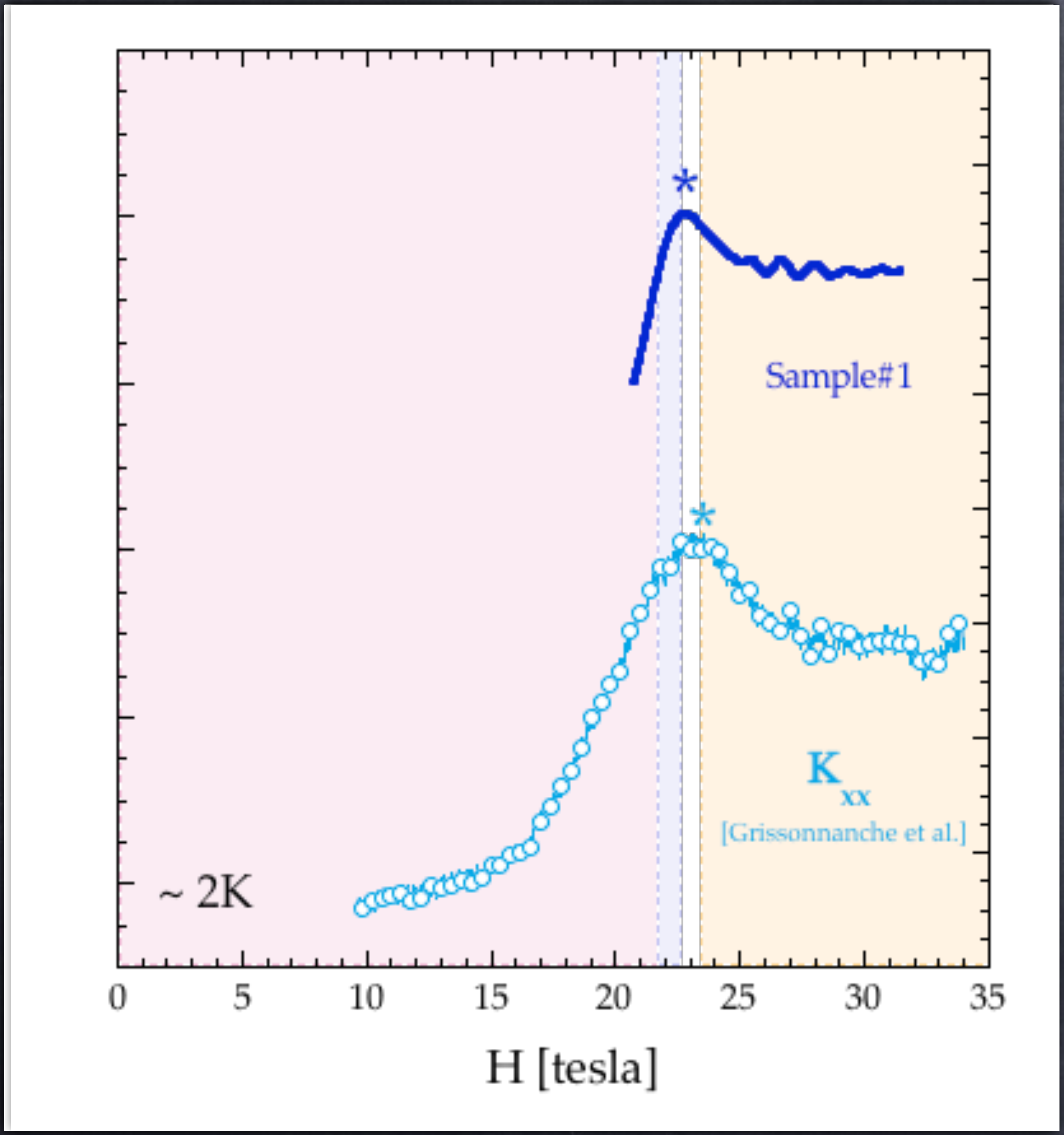

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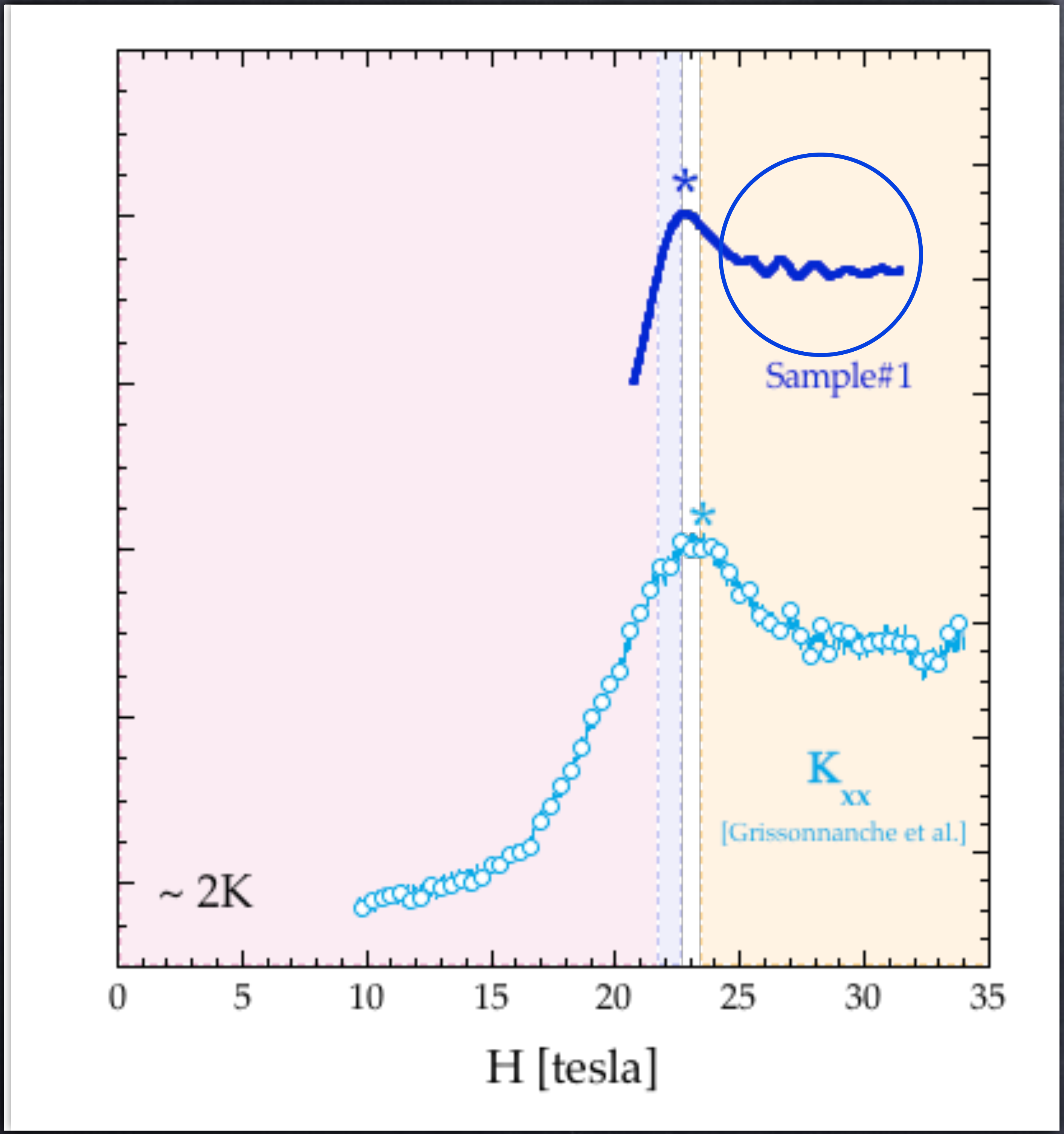


or 1 large crossover ?

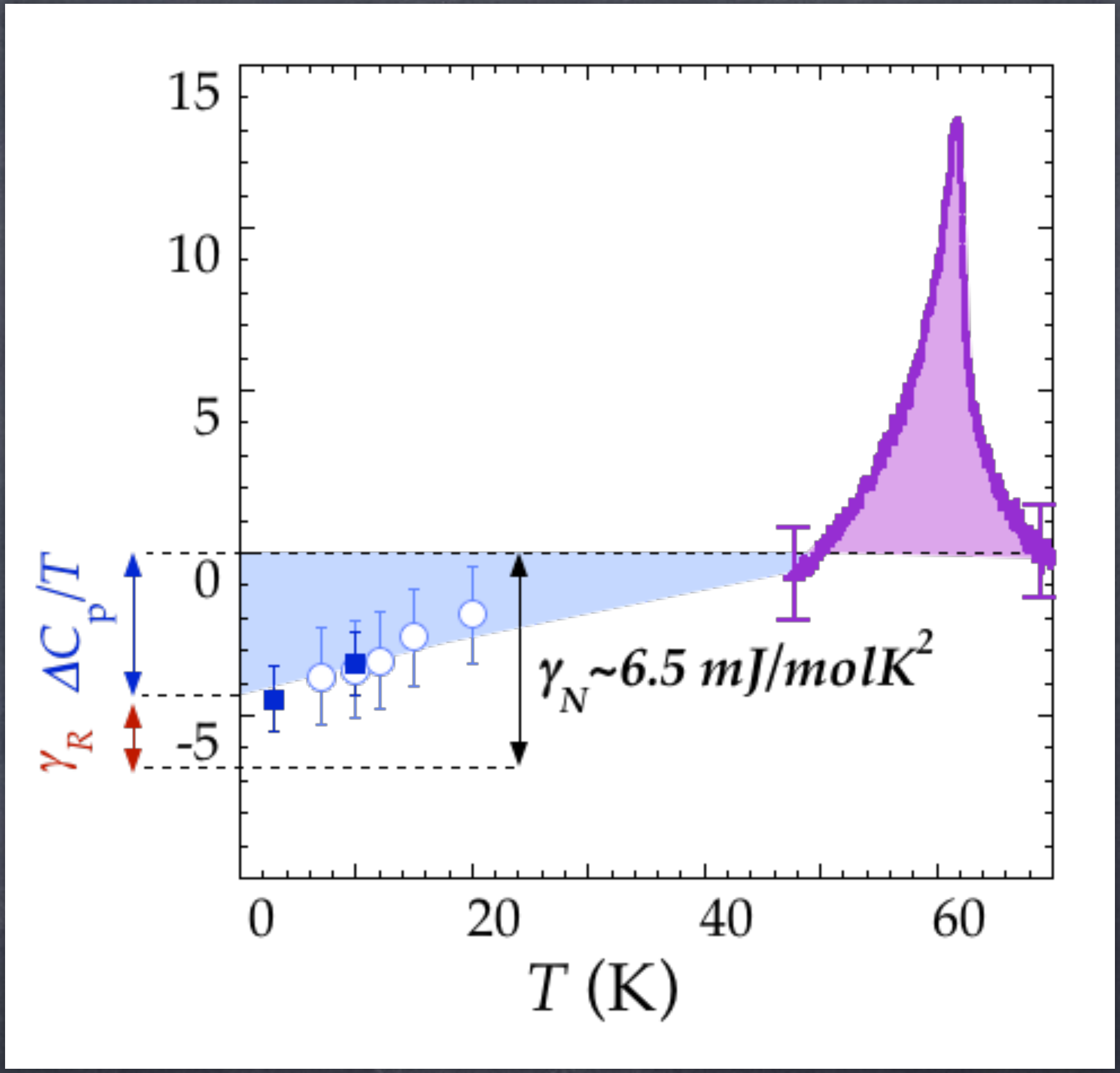
(with different criteria)

decreasing with T ?

quantum oscillations
clearly visible
for H > $H_{c2}(0)$ ~ 25T
with **m* =1.6**

Sommerfeld coefficient ?

$\Delta C_p/T$	4 ± 1
γ_R **residual value**	2.5 ± 0.5
TOTAL = γ_N mJ/molK²	6.5 ± 1



$$\gamma_N = 2.9 \ (\mathrm{mJ/molK^2}) \times \sum_i (n_i m_i / m_e)$$

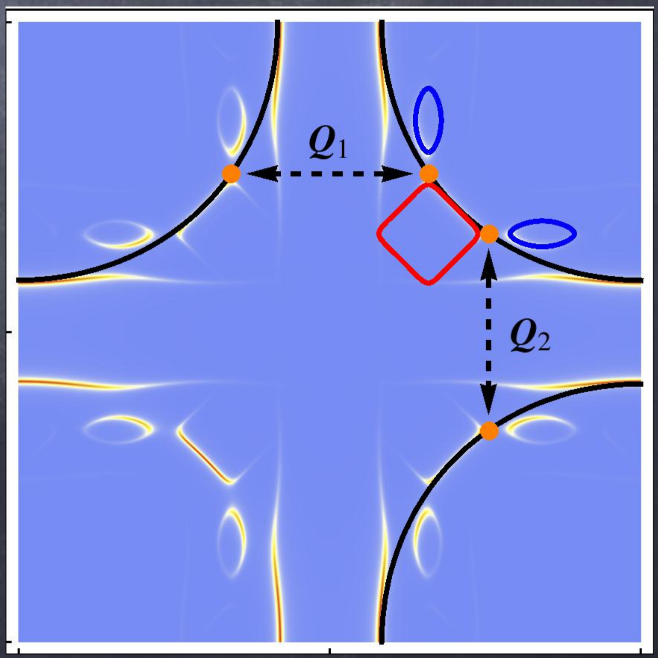
for 2 CuO_2 planes)

Sommerfeld coefficient ?

$\Delta C_p/T$	4 ± 1	4.9 ± 0.6	1 electron pocket m_e = 1.7
γ_R **residual value**	2.5 ± 0.5	2.6 ± 0.3	2 hole pockets m_h = 0.45
TOTAL = γ_N $mJ/molK^2$	6.5 ± 1	7.5 ± 0.9	TOTAL $mJ/molK^2$

Good agreement

A. Allais et al. (2014)
Reconstruction model



but origin of γ_R ?

and $\Delta C_p/T$ close to the value expected for the electron pocket ?