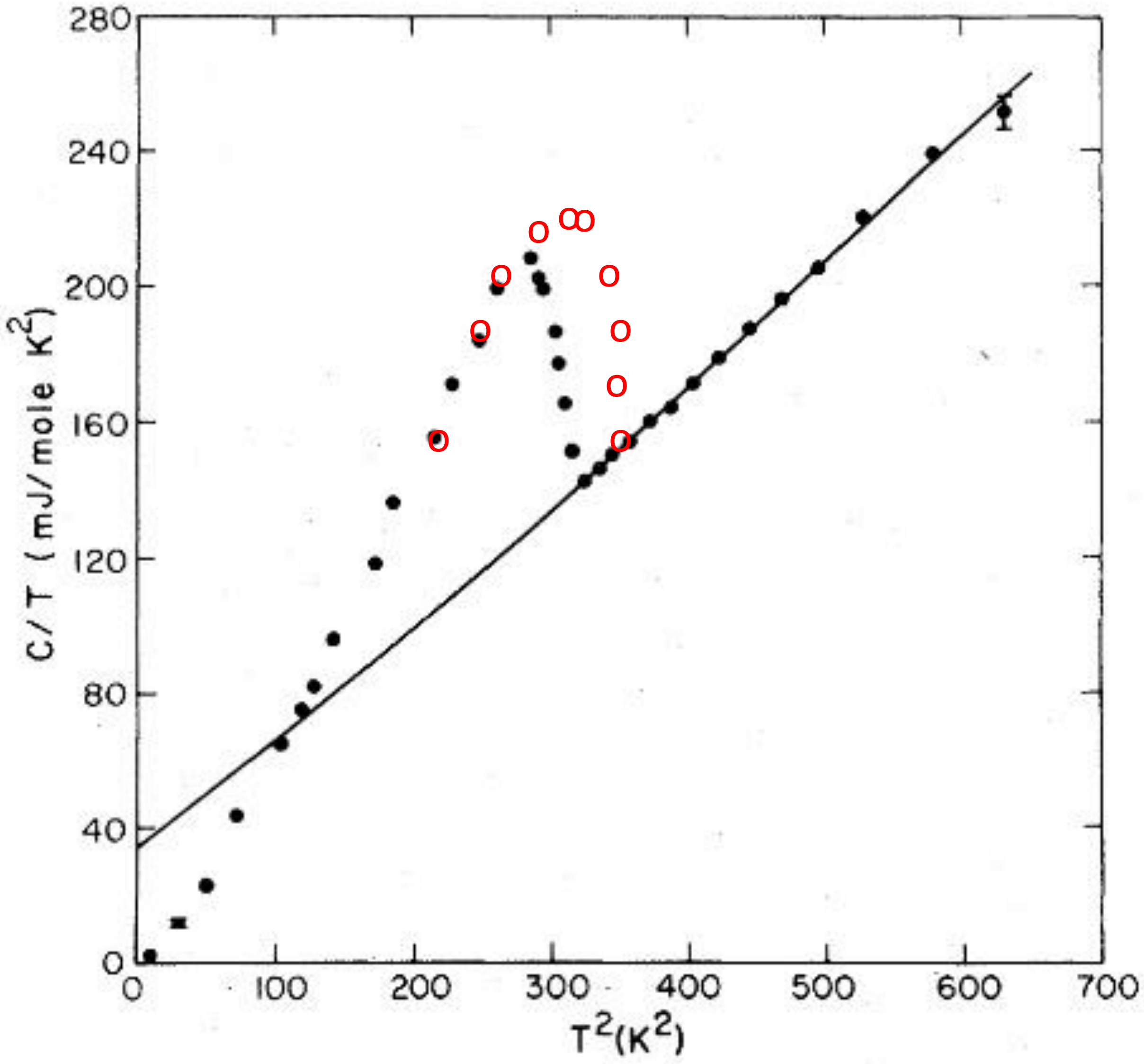
Puzzles in the Iron-Based Superconductors (IBS) From Specific Heat Measurements

Bulk transition width in IBS vs annealing

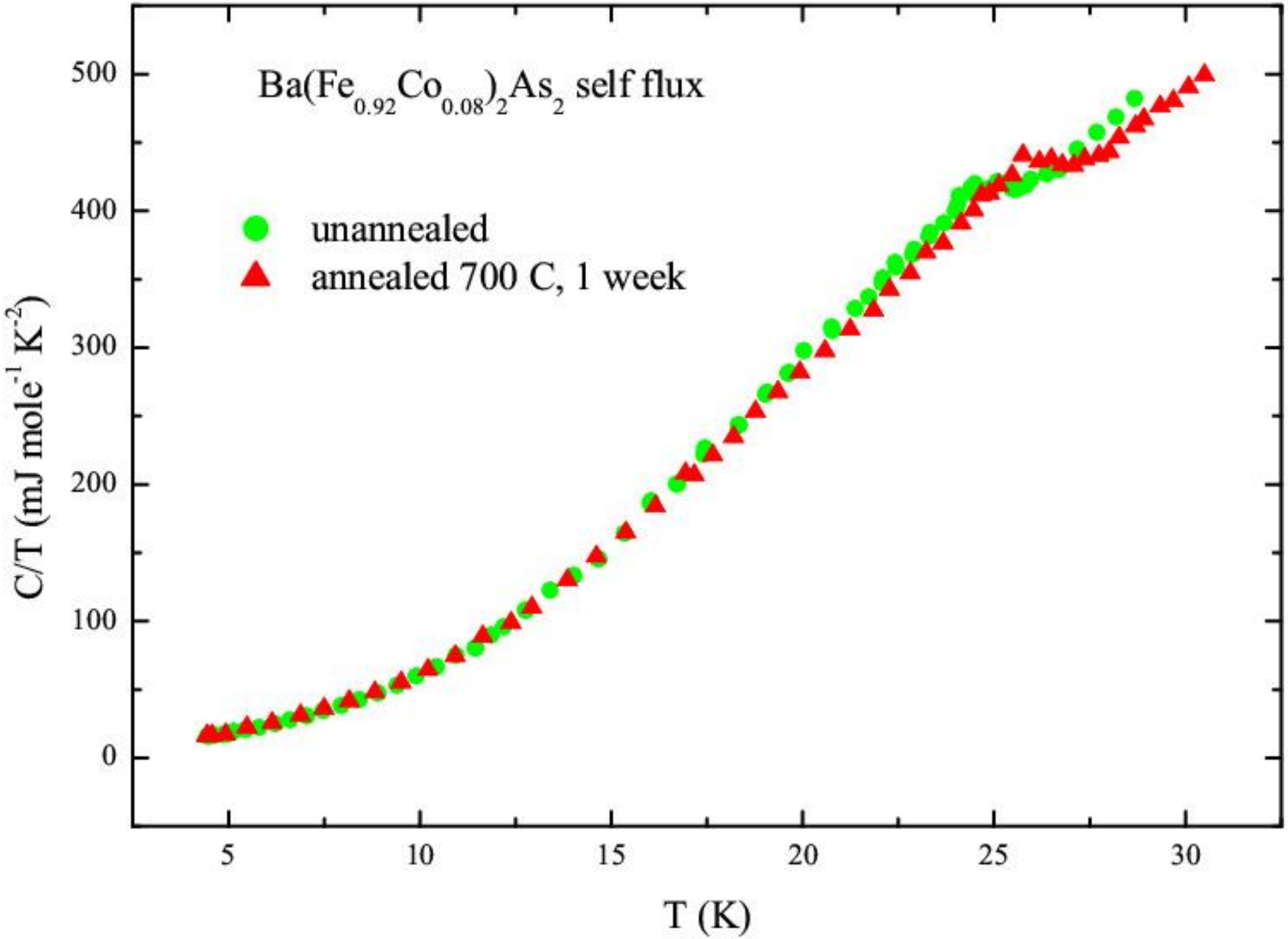
- Usually, when annealing a superconductor and T_c increases, then the bulk transition width (as measured by the specific heat) goes down.
- Example – A-15 Nb_3Al

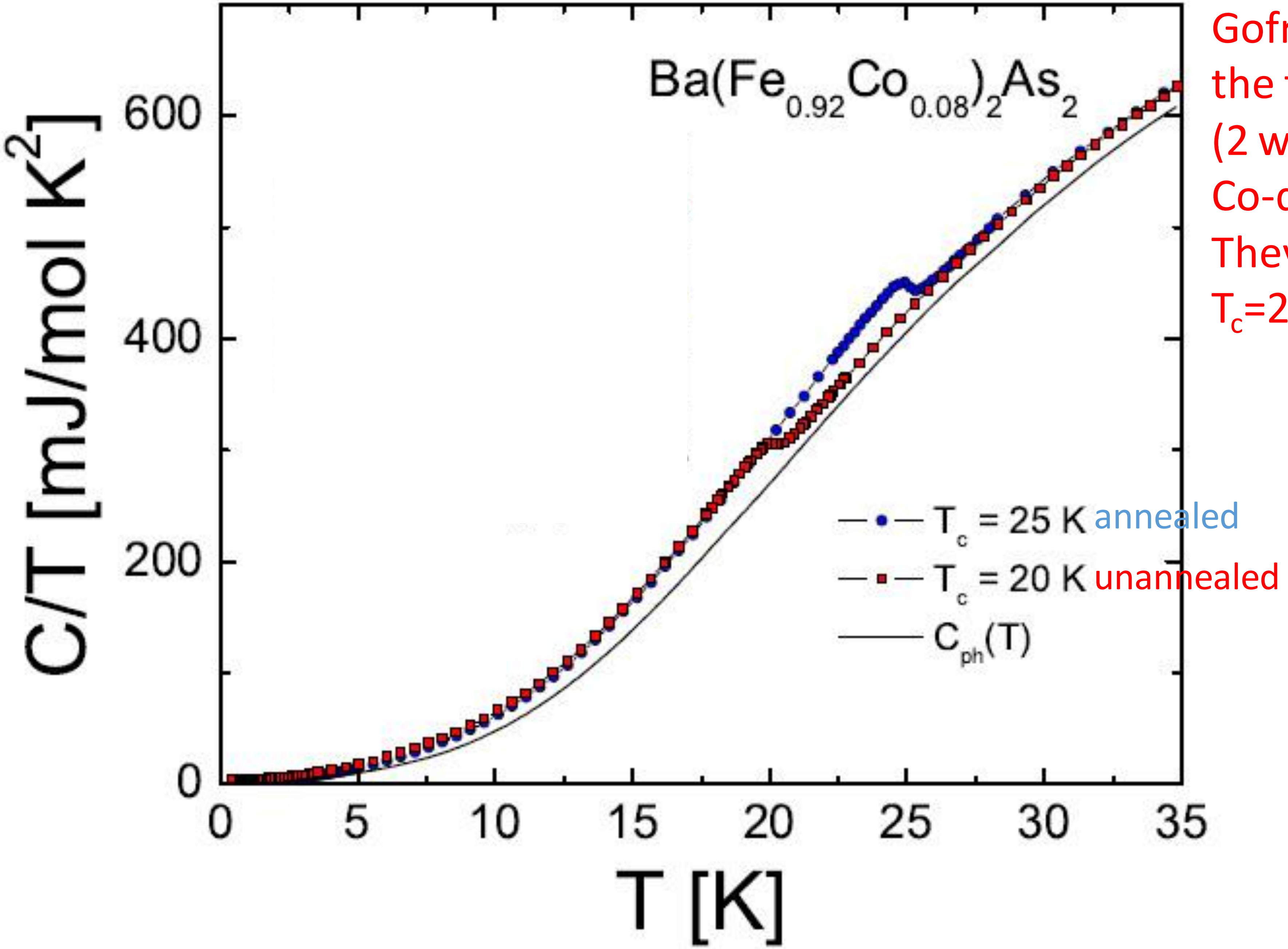
Irradiated Nb_3Al



Fluence	T_c(K)	ΔT_c(K)
0	18.8	0.6
1×10^{18} n/cm^2	17.9	1.0

Annealing of IBS



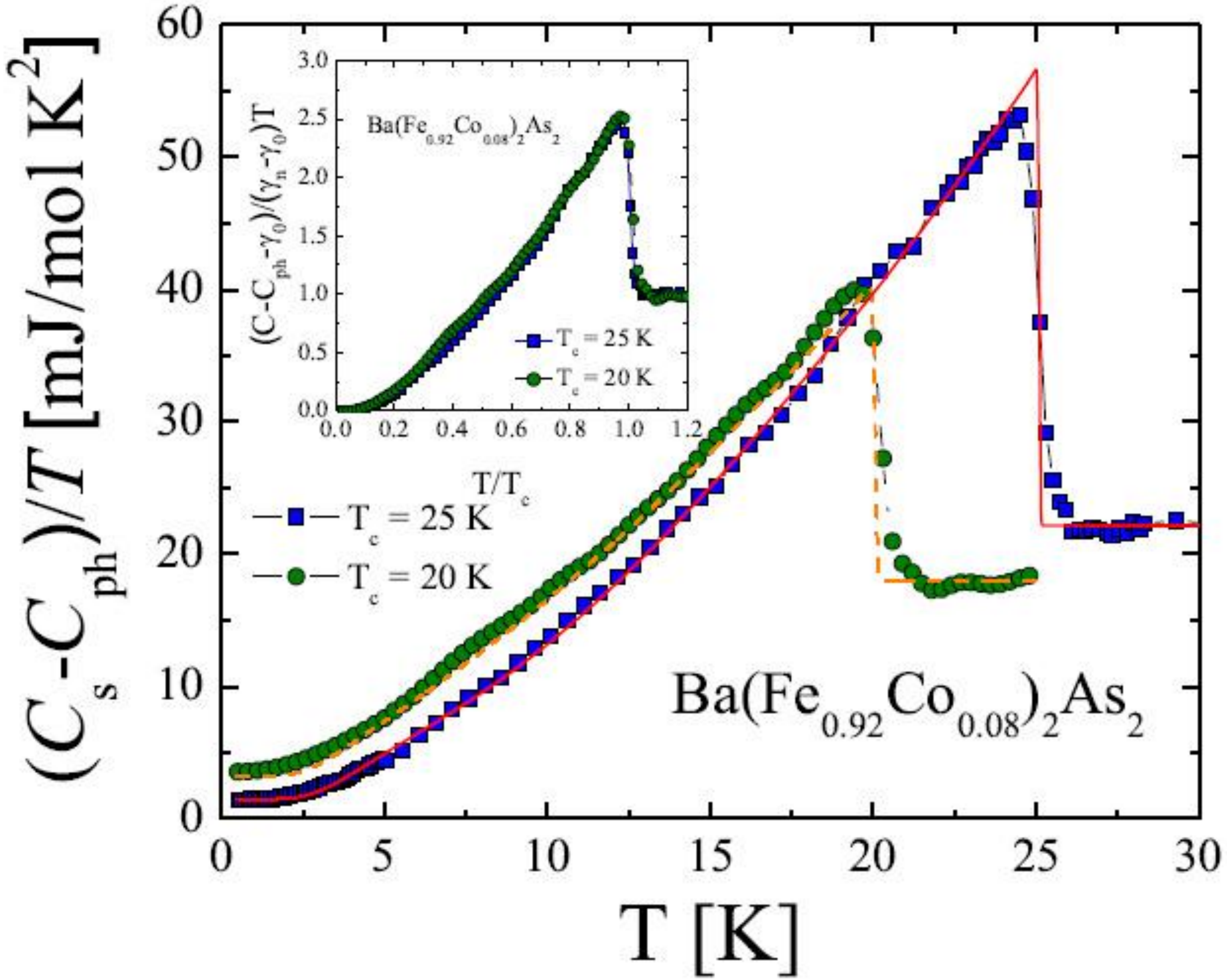


Gofryk et al. were the first to anneal (2 weeks, 800 ^{o}C) Co-doped $BaFe_2As_2$

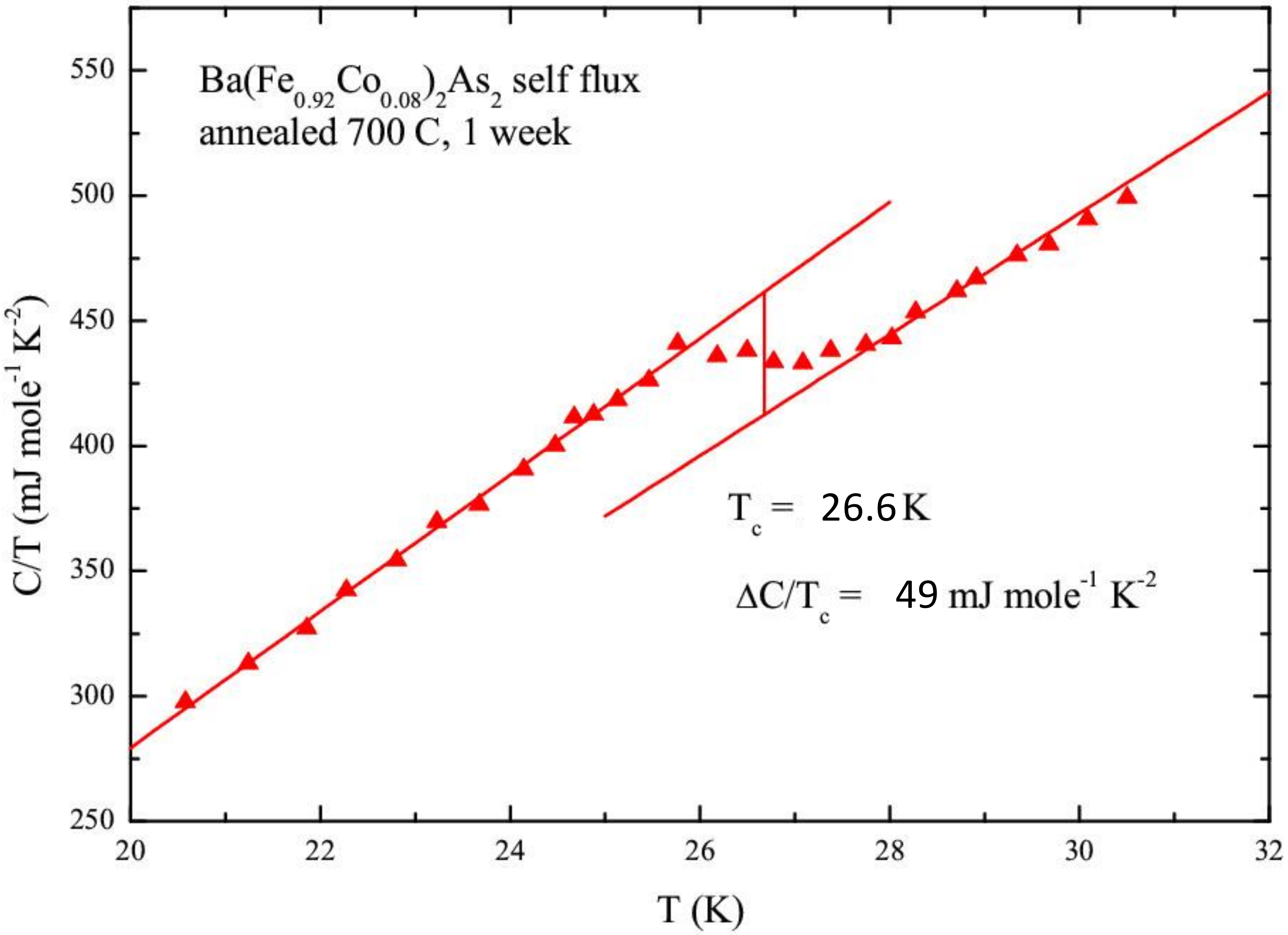
They got ΔT_c~1.3 K

T_c=25 K, $\Delta C/T_c$=34

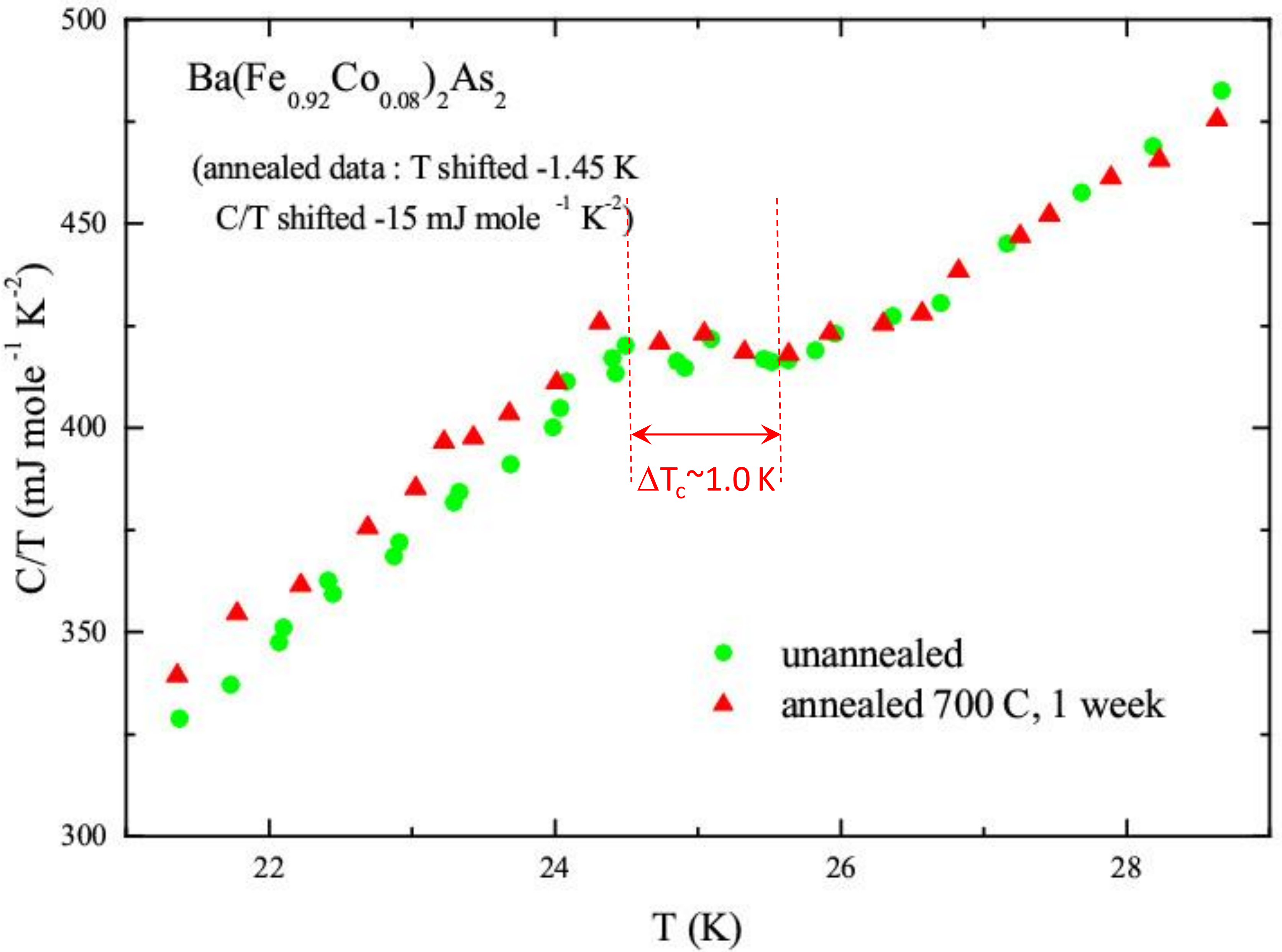
Warning – when estimating transition width (see previous slides), do not be confused by plots like the one below



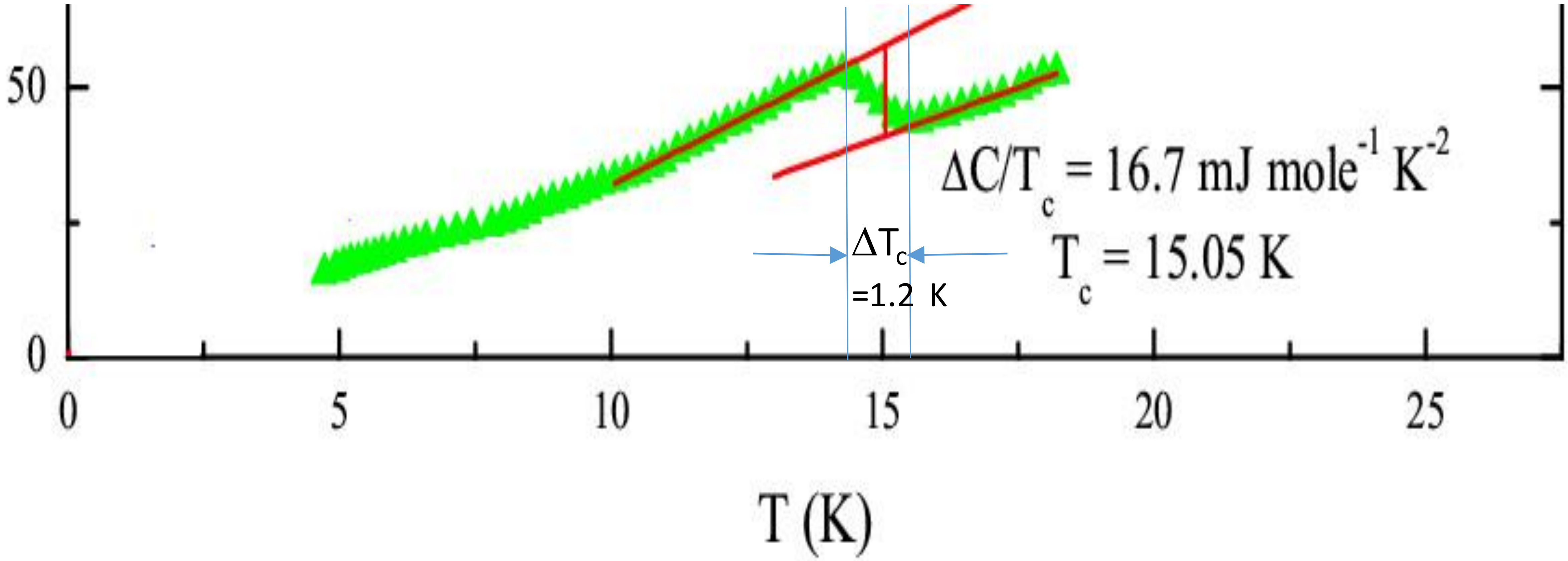
Expanded View of Our Annealed Data



Annealing of IBS



Question: What about Transition Width in un-doped IBS, unannealed LiFeAs



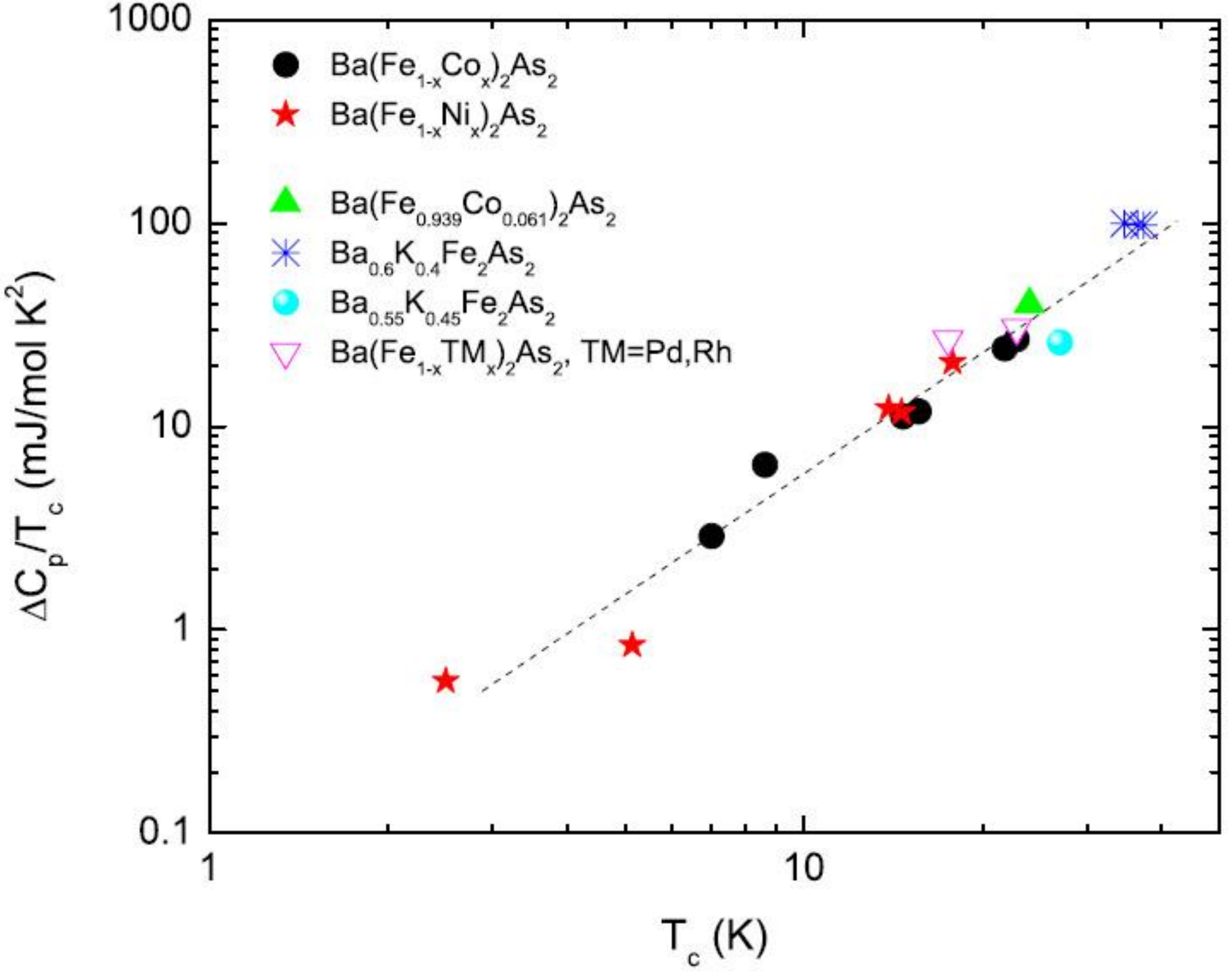
Why is the bulk superconducting transition in IBS so broad, even after annealing?

- Not reasonable to assume that IBS are in the strong pair breaking regime. If that were so, then much higher T_c's would be potentially possible.

Puzzle 2: Specific Heat ΔC vs T_c in Superconductors

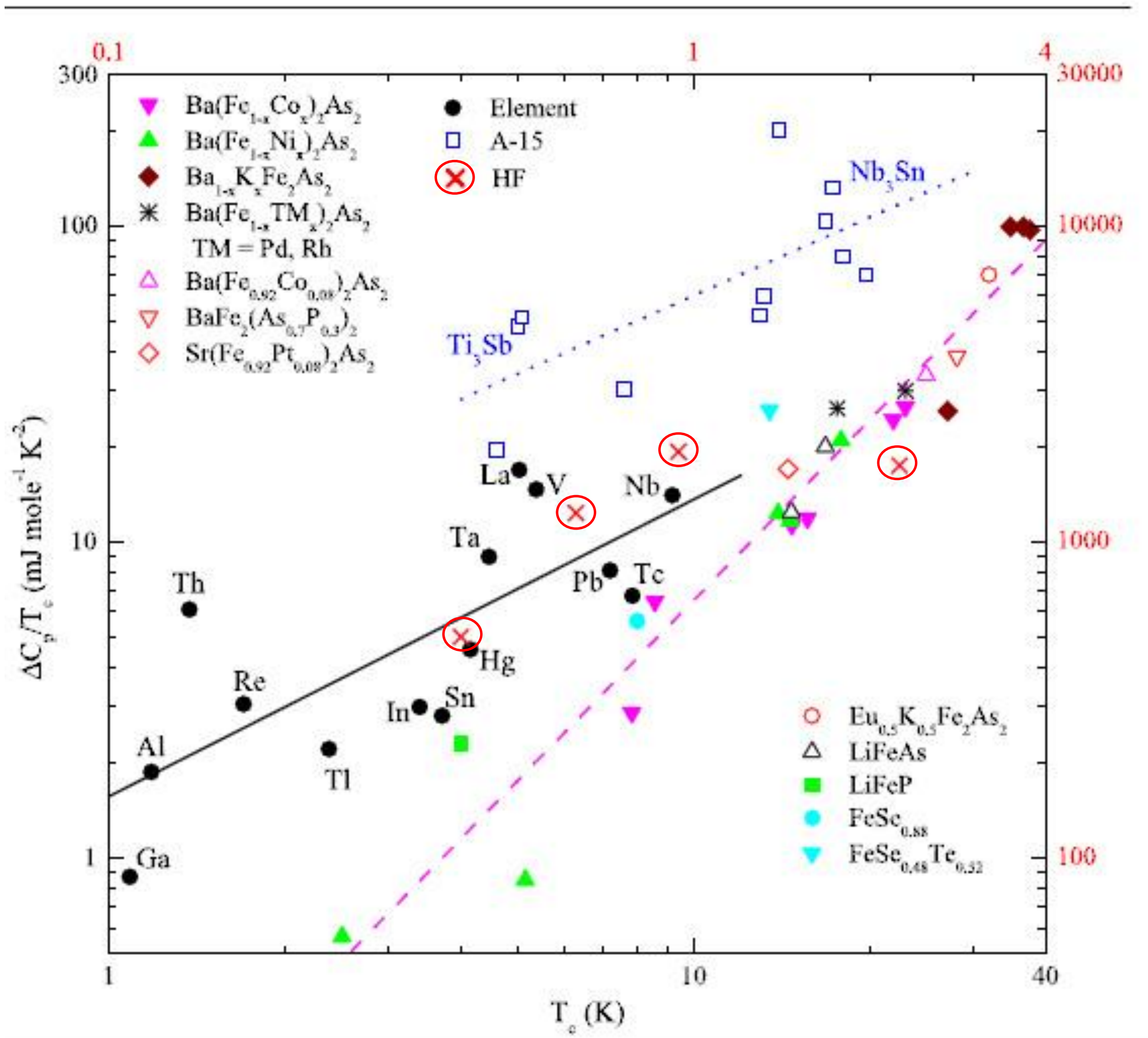
- Background/Progress Report

Bud'ko, Ni, Canfield noticed that $\Delta C/T_c \propto T_c^{\sim 2}$ in doped $BaFe_2As_2$ (PRB 2009)



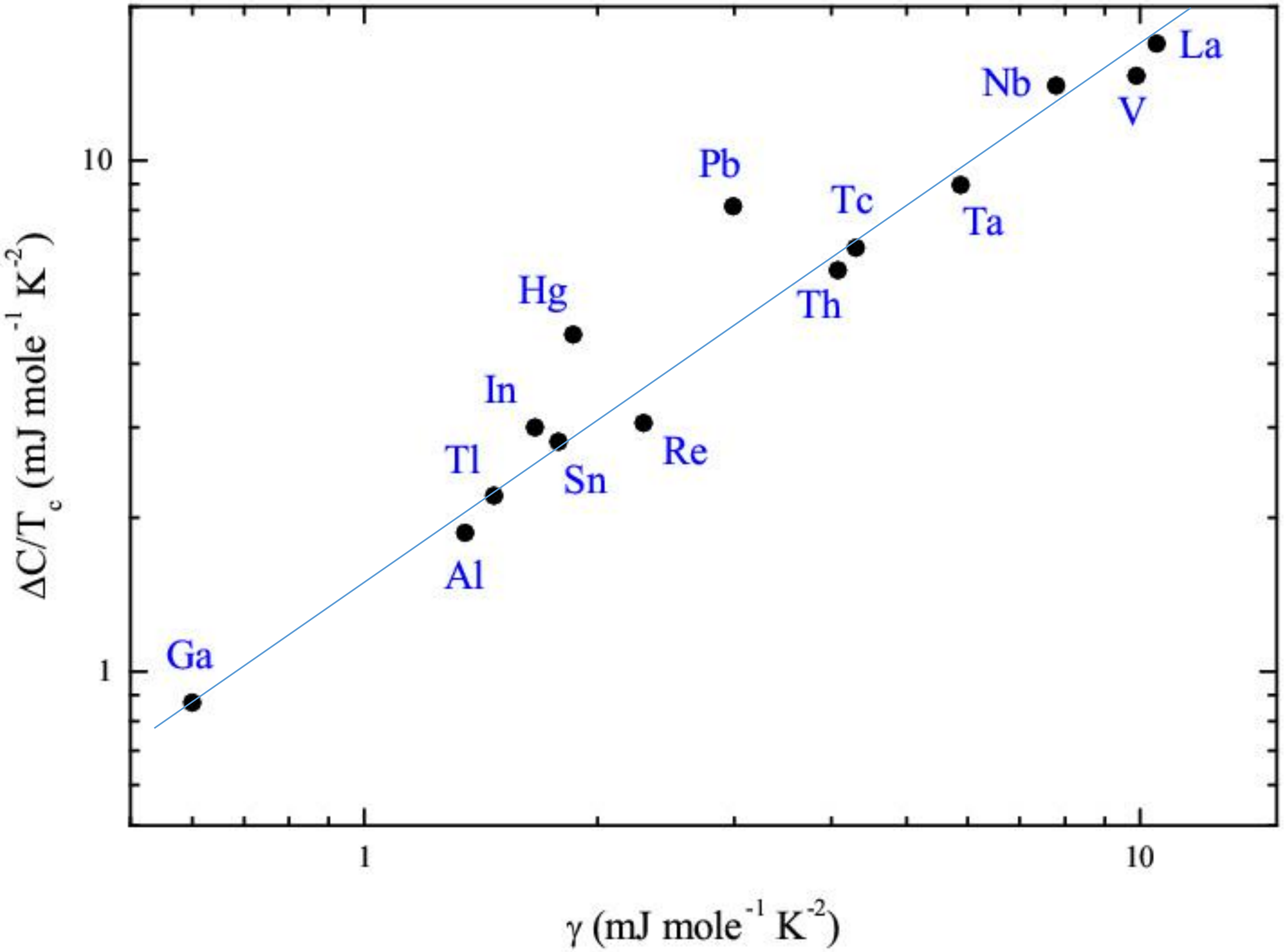
Kim et al., 2011: This $\Delta C/T_c \propto T_c^2$ is a.) true for most IBS and b.) not true for BCS superconductors, heavy Fermions, (cuprates?)

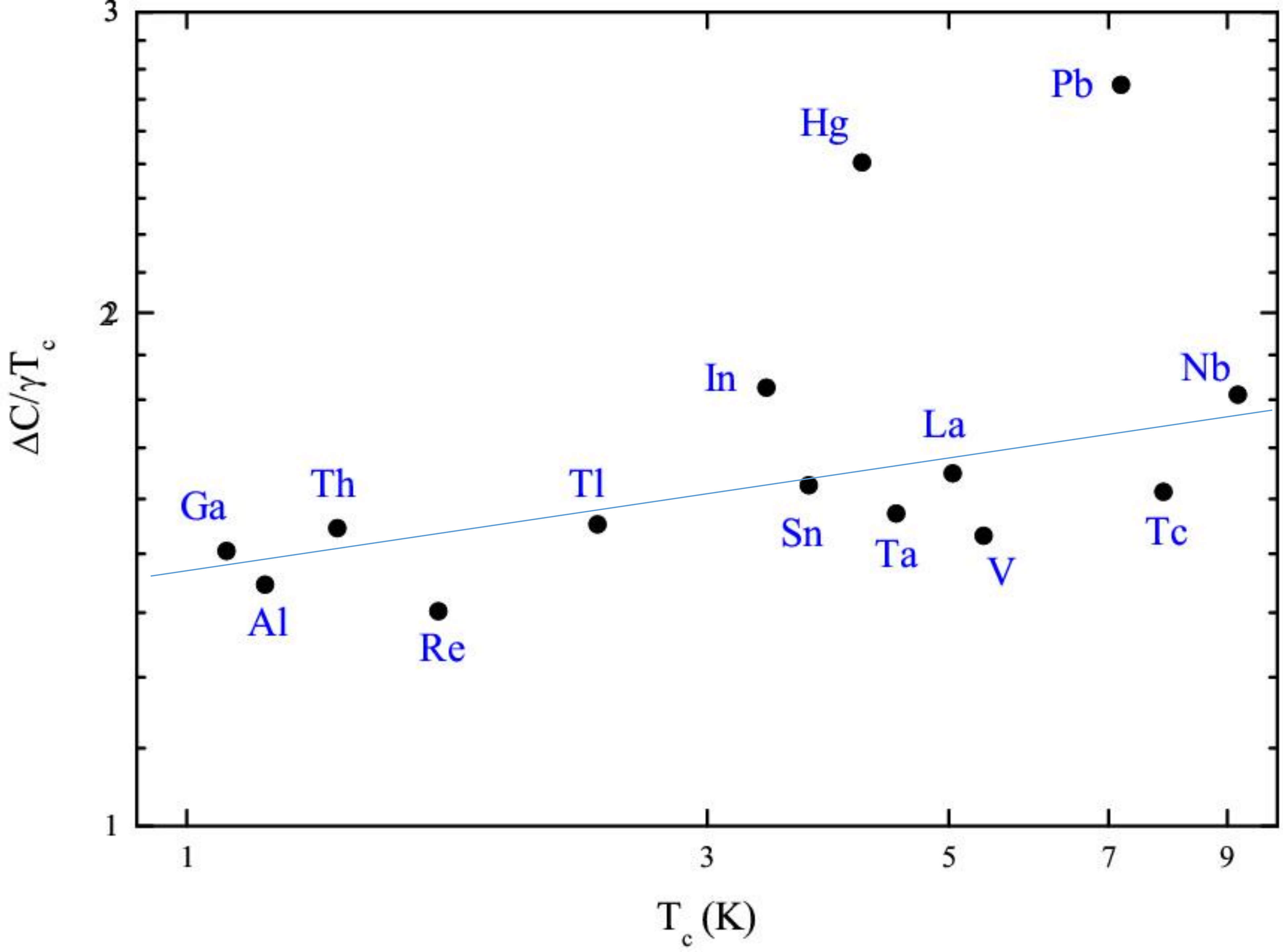
BCS: $\Delta C/\gamma T_c = 1.43$



Note:
BNC is not unusual based on large $\Delta C/T_c$ at *high* T_c but rather the quick fall off in $\Delta C/T_c$ at *lower* T_c

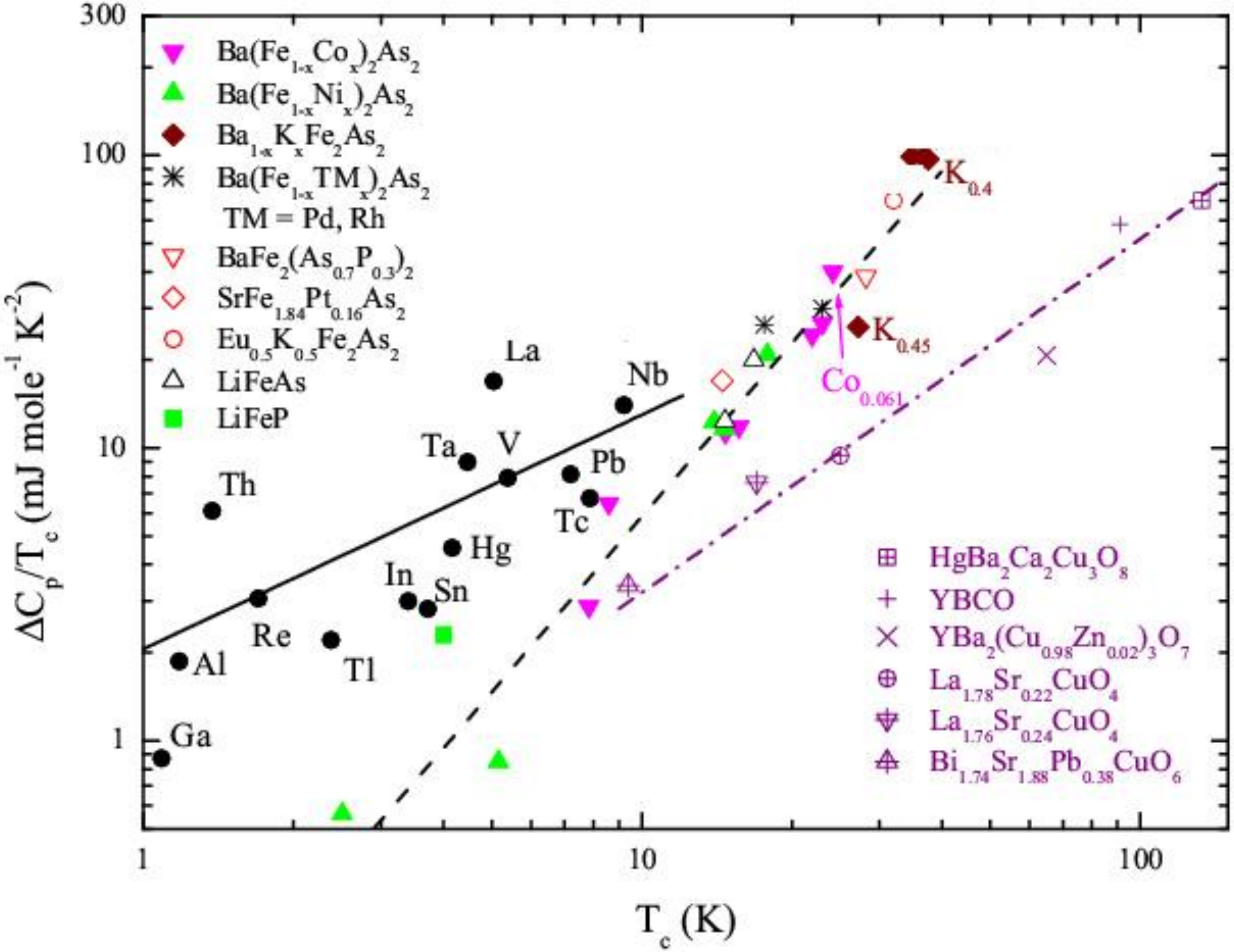
Instead of plotting $\Delta C/T_c$ vs T_c for the elements, try $\Delta C/T_c$ vs γ



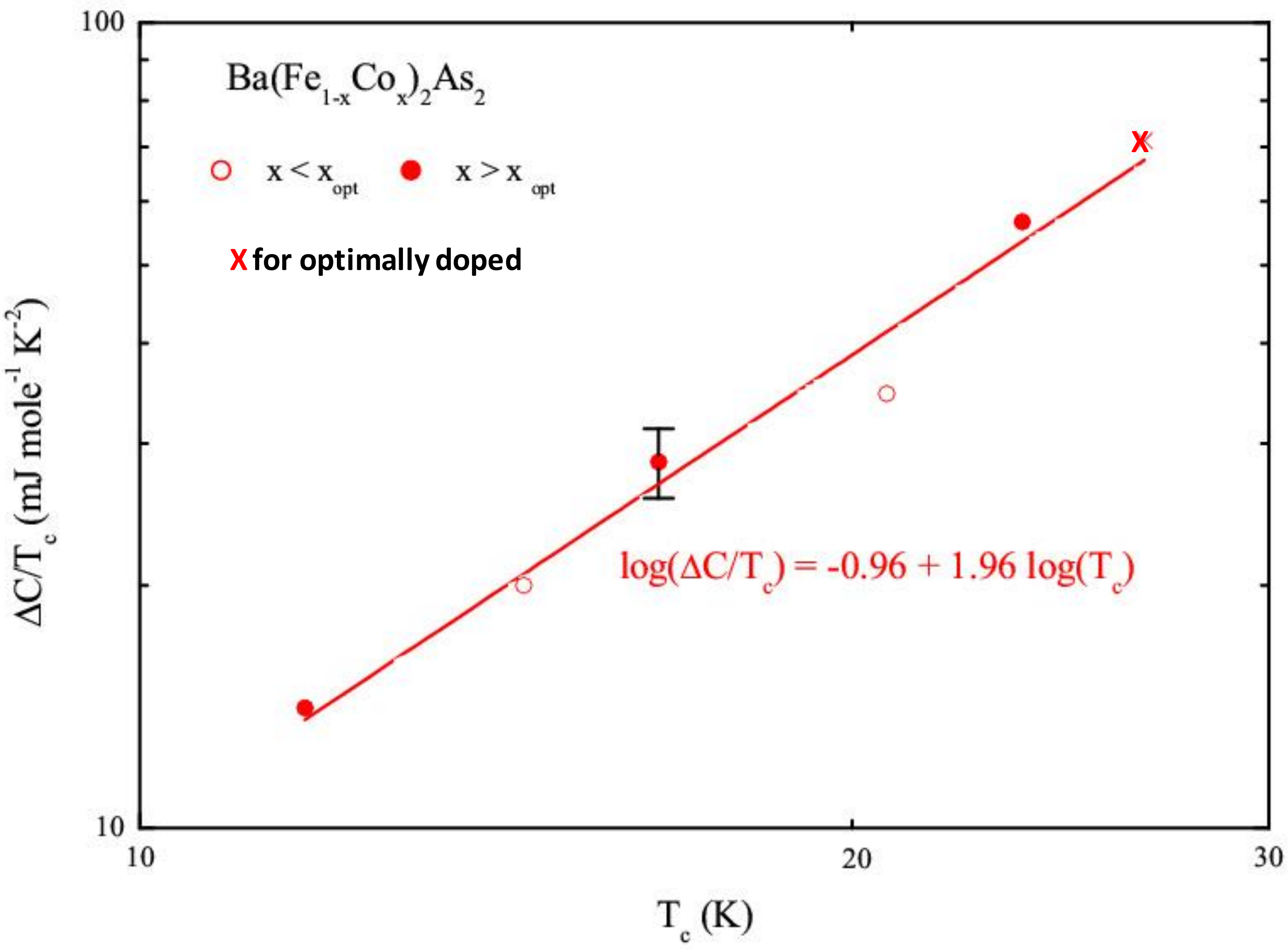


3
2
1
ΔC/γT_c
1
3
5
7
9
T_c (K)
Pb
Hg
In
Nb
La
Th
Tl
Ga
Sn
Ta
V
Tc
Al
Re

BNC for IBS compared to Cuprates (avoiding pseudogap)



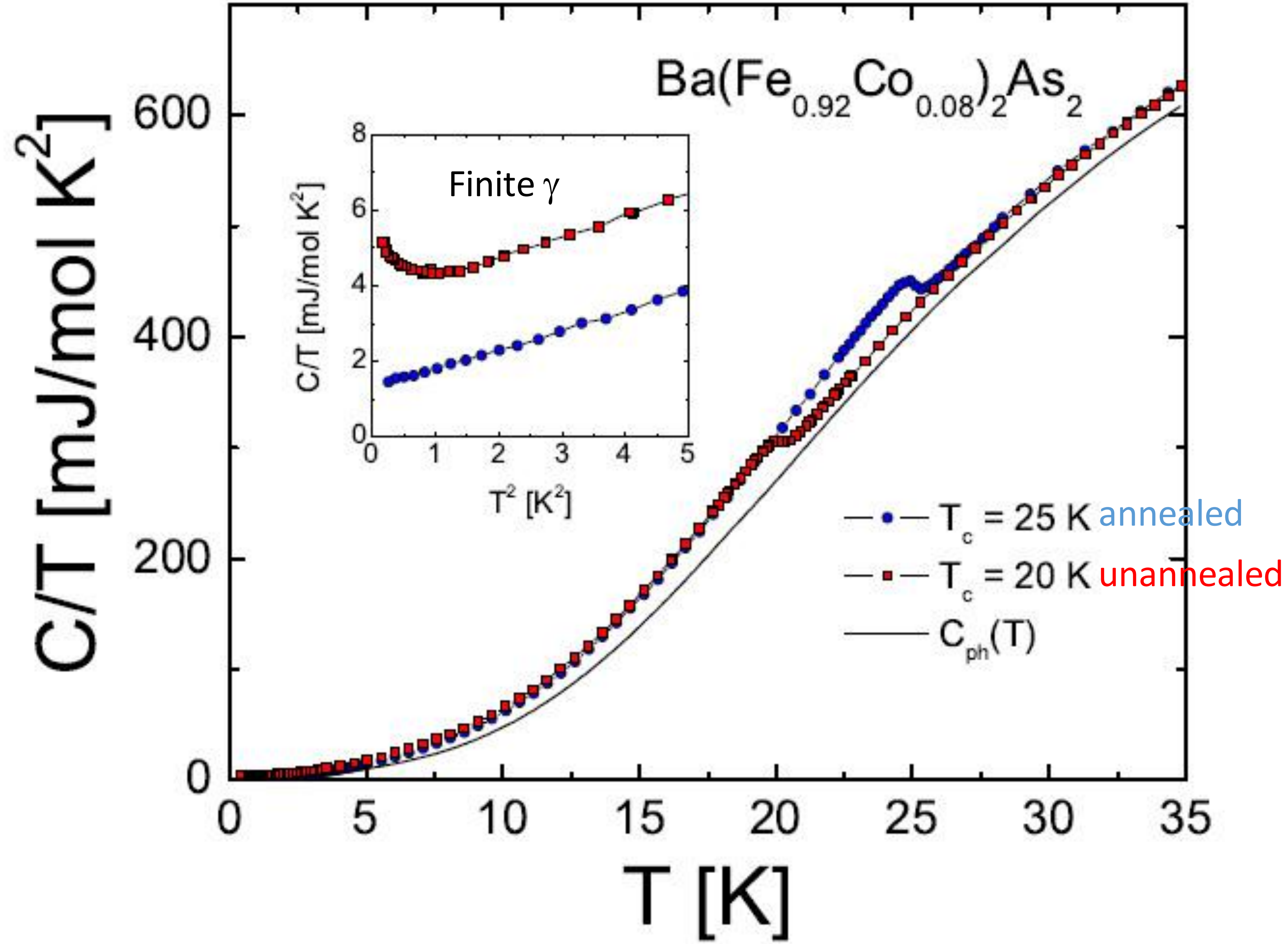
Result of careful measurement of $\Delta C/T_c$ in annealed $Ba(Fe_{1-x}Co_x)_2As_2$



Result: no apparent difference in rate of falloff of $\Delta C/T_c$ for under- vs over-doped, i. e. $\Delta C/T_c$ seems disconnected from the SDW magnetism

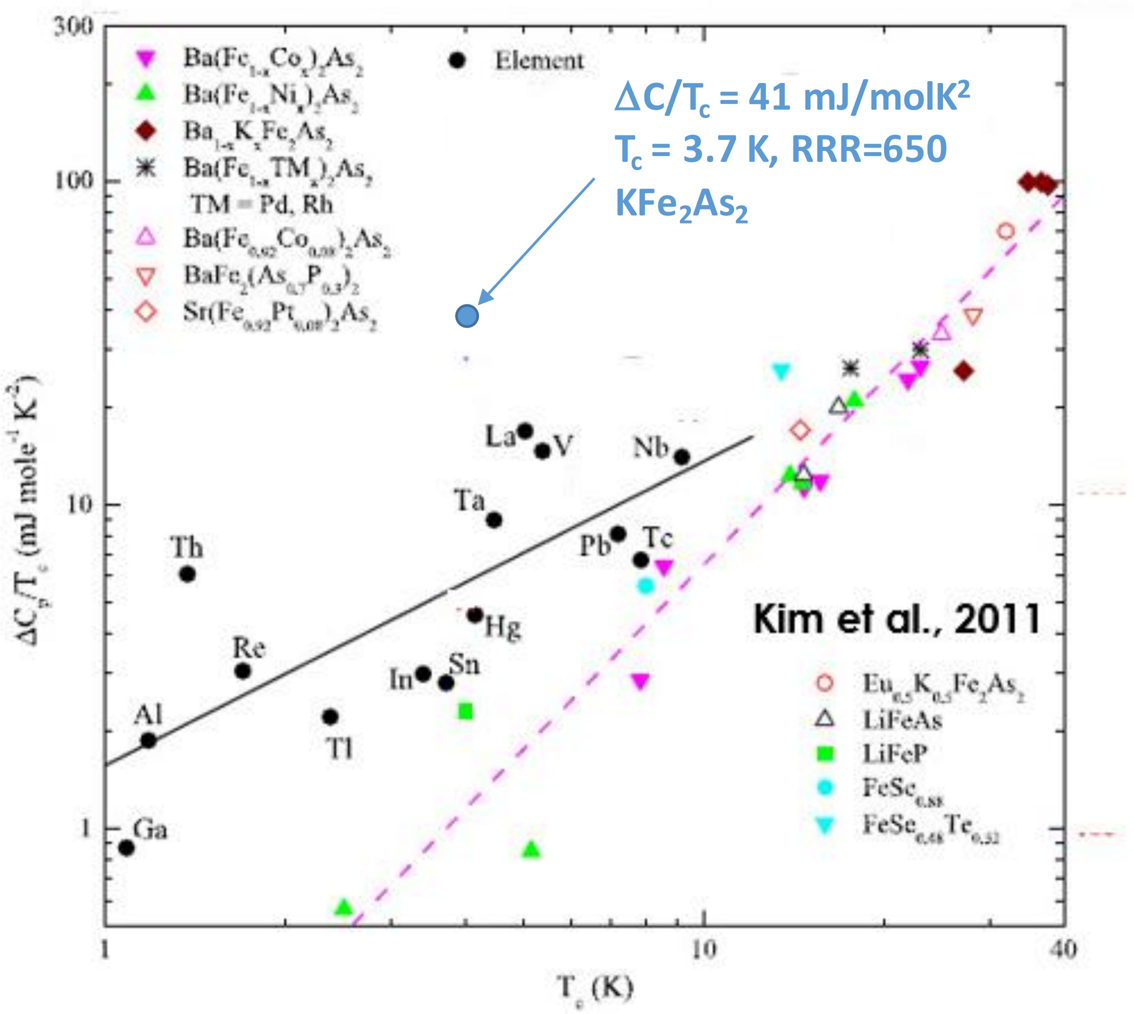
Result of careful measurement of $\Delta C/T_c$ in annealed $Ba(Fe_{1-x}Co_x)_2As_2$

- It's not just annealing to try to optimize ΔC, it's also a question of normalizing ΔC based on finite γ at low temperature in the superconducting state



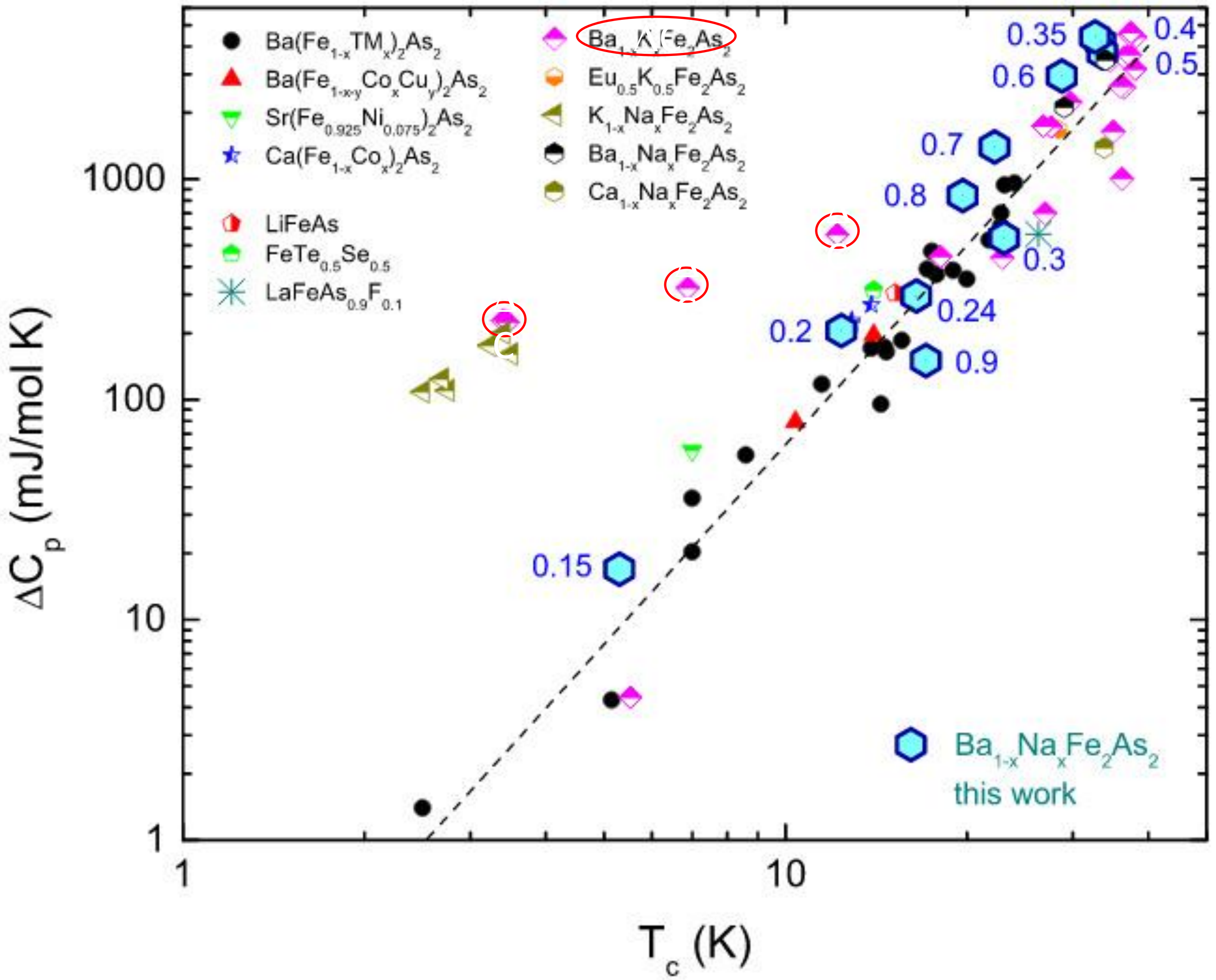
Ba(Fe0.92Co0.08)2As2
Finite γ
C/T [mJ/mol K2]
T2 [K2]
0
2
4
6
8
1
3
5
C/T [mJ/mol K2]
0
200
400
600
5
10
15
20
25
30
35
T [K]
Tc = 25 K annealed
Tc = 20 K unannealed
Cph(T)

New Subject: This $\Delta C/T_c$ correlation with T_c is useful for identifying materials that do not belong to the class of IBS

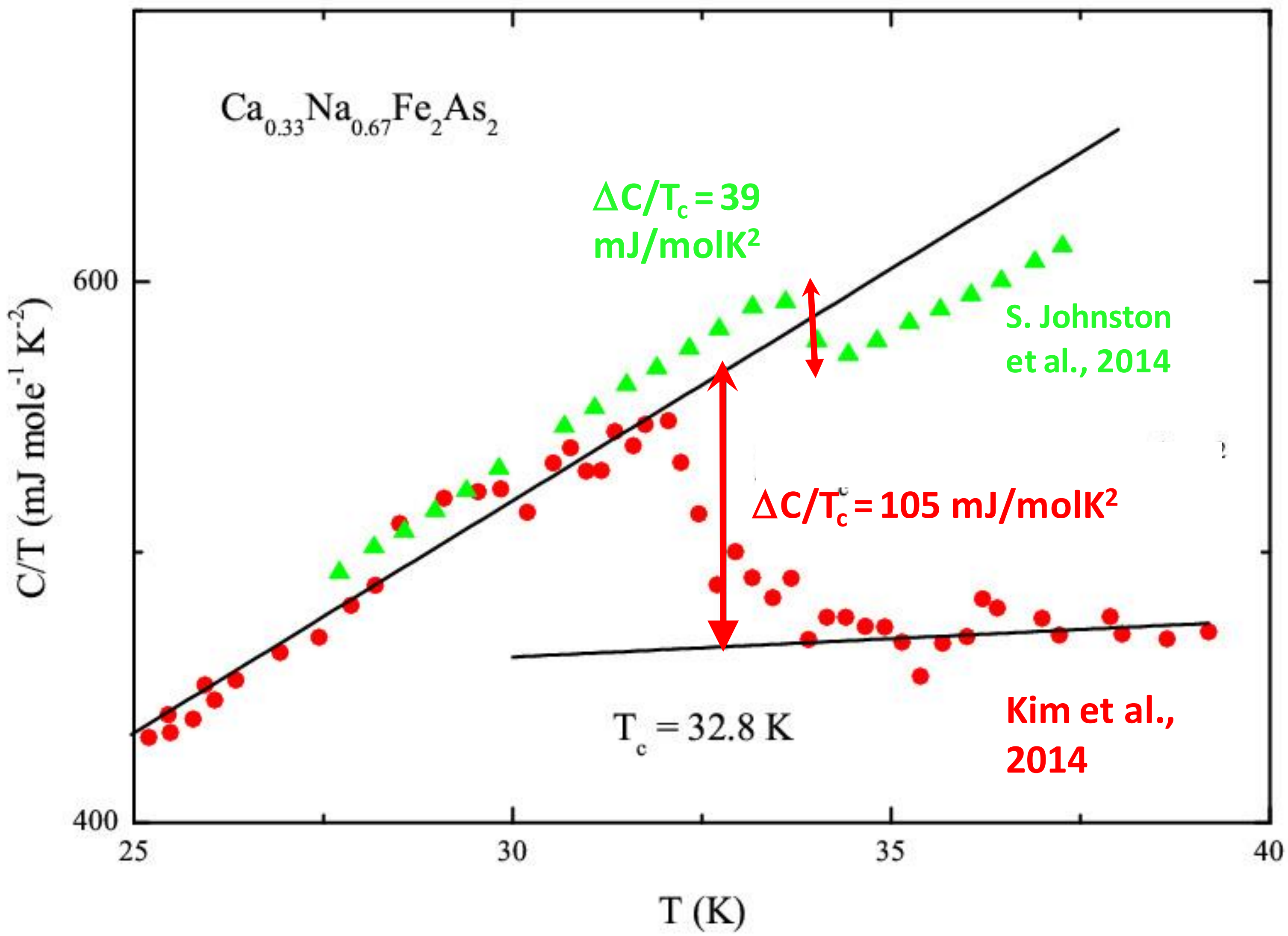


e. g. KFe_2As_2, $RbFe_2As_2$, and $CsFe_2As_2$ – all with T_c's < 4 K

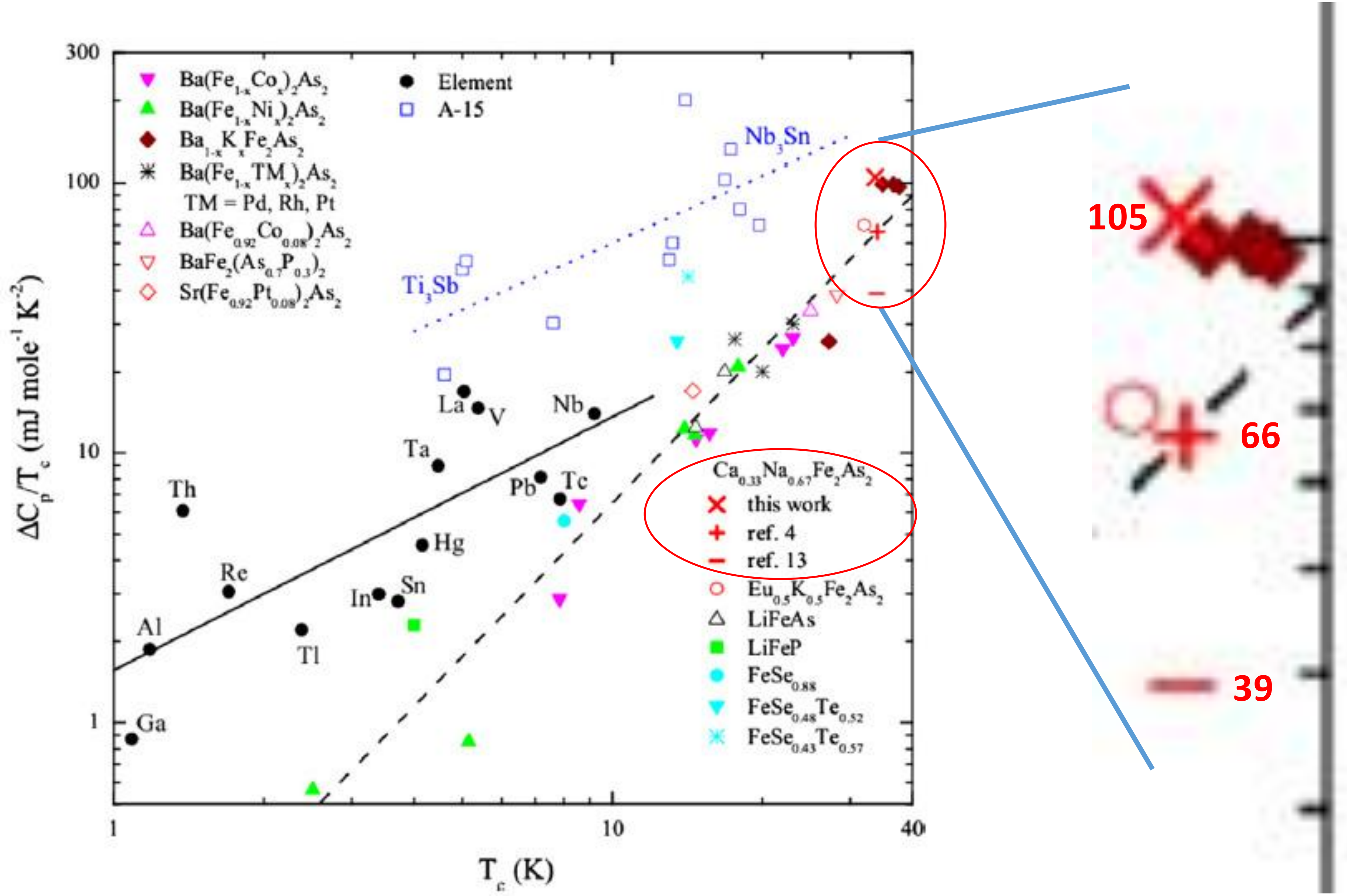
Recent work of Bud'ko et al., PRB 89, 014510 (2014) (note that plot is of ΔC, not $\Delta C/T_c$



$\Delta C/T_c$ is an important key to estimating sample quality, e. g. in $Ca_{0.33}Na_{0.67}Fe_2As_2$



“the specific heat jump at *Tc* obtained for this material scales ***relatively well*** with its *Tc*”



Question: As samples become better (larger ΔC values), how will the exponent α in $\Delta C/T_c \sim T_c^{\alpha}$ vary?