nature

SUPPLEMENTARY INFORMATION

https://doi.org/10.1038/s41586-019-0932-x

In the format provided by the authors and unedited.

Thermodynamic signatures of quantum criticality in cuprate superconductors

B. Michon[1,2,3], C. Girod[1,2,3], S. Badoux[2], J. Kačmarčík[4], Q. Ma[5], M. Dragomir[6], H. A. Dabkowska[6], B. D. Gaulin[5,6,7], J.-S. Zhou[8], S. Pyon[9], T. Takayama[9], H. Takagi[9], S. Verret[2], N. Doiron-Leyraud[2], C. Marcenat[10], L. Taillefer[2,7]* & T. Klein[1,3]*

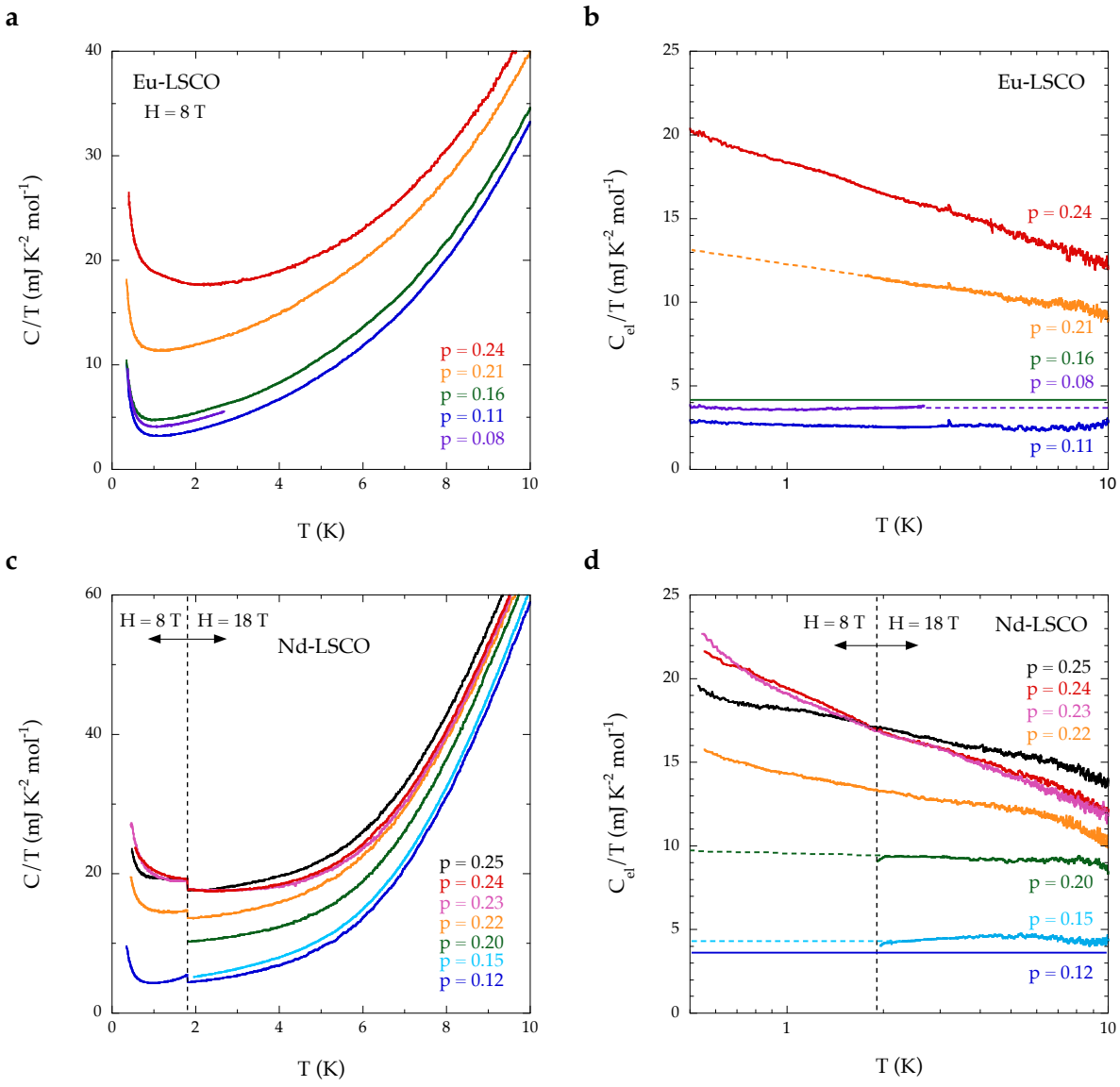
[1]Institut Néel, Université Grenoble Alpes, Grenoble, France. [2]Institut quantique, Département de physique and RQMP, Université de Sherbrooke, Sherbrooke, Québec, Canada. [3]CNRS, Institut Néel, Grenoble, France. [4]Institute of Experimental Physics, Slovak Academy of Sciences, Košice, Slovakia. [5]Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, Canada. [6]Brockhouse Institute for Materials Research, McMaster University, Hamilton, Ontario, Canada. [7]Canadian Institute for Advanced Research, Toronto, Ontario, Canada. [8]Materials Science and Engineering Program, Department of Mechanical Engineering, University of Texas at Austin, Austin, Texas, USA. [9]Department of Advanced Materials Science, University of Tokyo, Kashiwa, Japan. [10]Université Grenoble Alpes, CEA, INAC, PHELIQS, LATEQS, Grenoble, France. *e-mail: louis.taillefer@usherbrooke.ca; thierry.klein@neel.cnrs.fr

SUPPLEMENTARY INFORMATION

Thermodynamic signatures of quantum criticality in cuprate superconductors

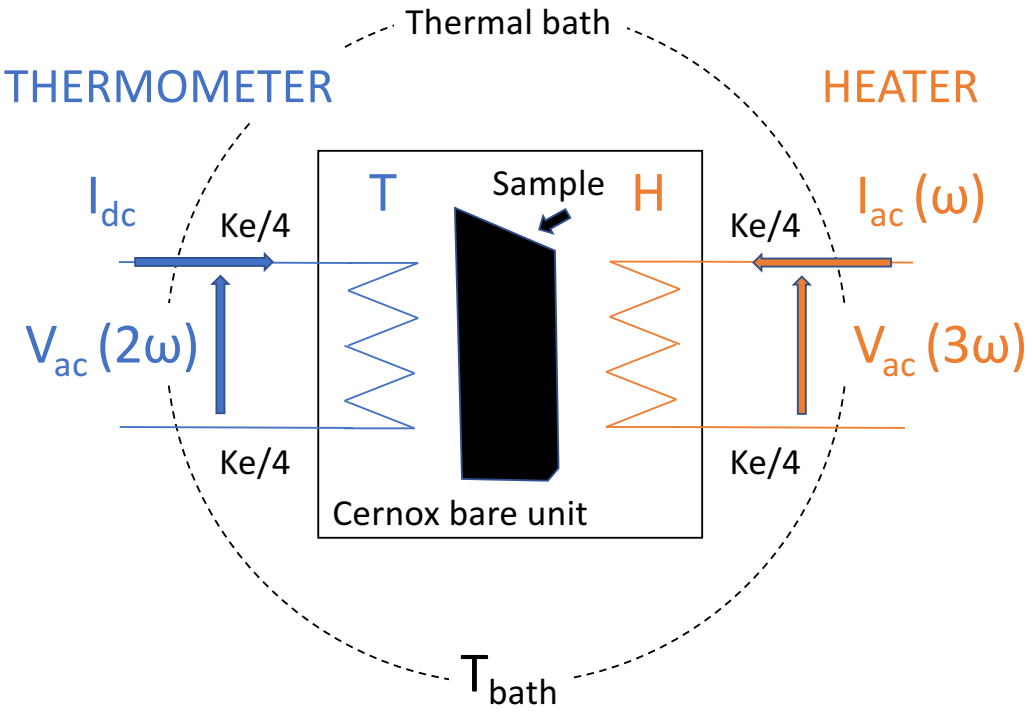
B. Michon *et al*.

CONTENTS



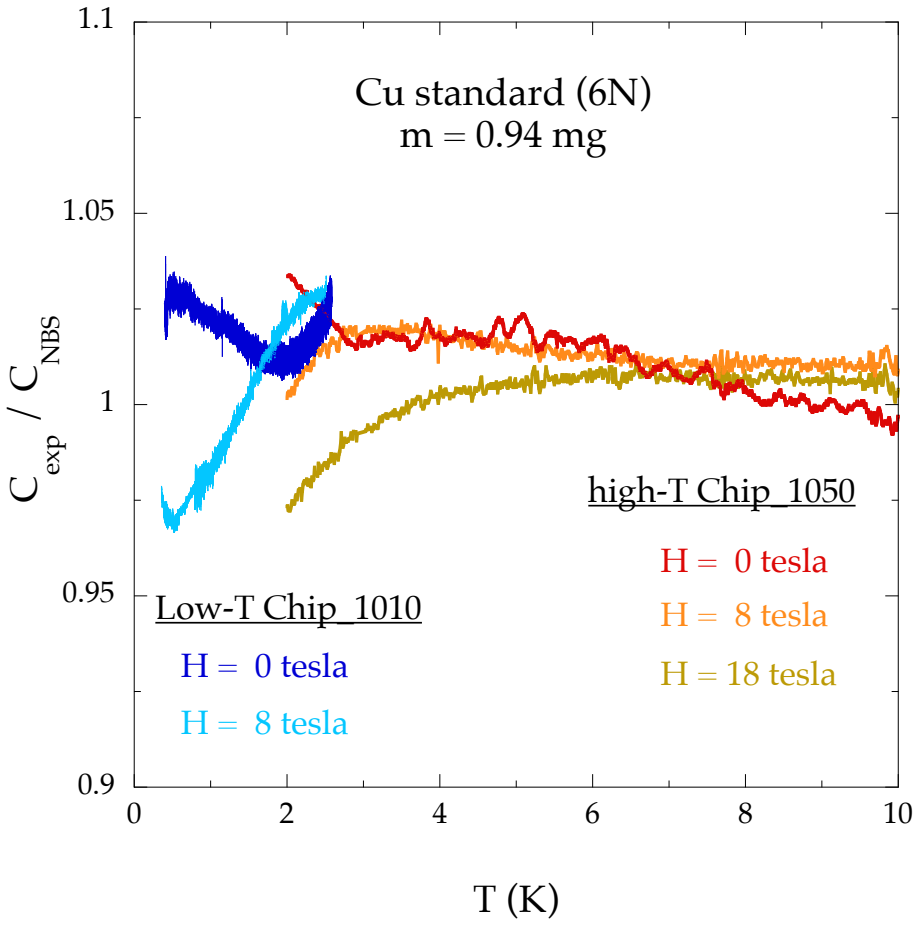
Supplementary Fig. 1 | Specific heat data for all crystals of Eu-LSCO and Nd-LSCO.

a) Specific heat of our five Eu-LSCO crystals measured in a field H = 8 T, down to 0.4 K. The rapid rise below 1 K is a nuclear Schottky anomaly (C_{nuclear}). **b)** Electronic specific heat $C_{\text{el}}(T)$ of those five Eu-LSCO crystals, plotted as C_{el}/T vs log$T$, from data at H = 8 T (p = 0.08, 0.11, 0.16, and 0.24) and at H = 18 T (p = 0.21). $C_{\text{el}}(T)$ is defined as $C_{\text{el}}(p; T) = C(p; T) - C(p=0.16; T) + \gamma$, where γ = 4.2 mJ /K^2 mol is the residual linear term of the p = 0.16 reference data ($C / T = \gamma + \beta T^2$, in Fig. 2a). Dashed lines are a linear extrapolation of the data (p = 0.21, orange; p = 0.08, purple). **c)** Same as panel **a**, for our seven Nd-LSCO crystals (H = 8 T, below the dashed line; H = 18 T, above the dashed line). **d)** Same as panel **b**, for those seven crystals, using data at p = 0.12 as the reference curve for subtraction, with γ = 3.6 mJ /K^2 mol (Fig. 2c).



Supplementary Fig. 2 | Experimental setup for the measurement of heat capacity.

Sketch of our experimental setup, showing the bare Cernox chip (black square) suspended by four PtW wires. A shallow groove is made with a wire saw to obtain two independent sides, one for the heater (H, right side) and one for the thermometer (T, left side). The sample is glued with a minute amount of Apiezon grease on the back of the sapphire substrate. An AC current I_{ac} at a frequency ω is applied across the heater to induce temperature oscillations of the small platform (sample + Cernox). A DC current I_{dc} is applied across the thermometer whose voltage is demodulated at 2ω (see METHODS – Specific heat measurements).



Supplementary Fig. 3 | Test of our specific heat measurement on a Cu sample.

Specific heat C_{exp} of a sample of copper measured using the same setup and analysis as used for our samples of Eu-LSCO and Nd-LSCO, plotted as C_{exp} / C_{NBS} vs T, where C_{NBS} is the standard value of the specific heat of copper established by the National Bureau of Standards. The measured data never deviate by more than 2-3 % from the standard, over the full temperature range from 0.5 K to 10 K, whether taken in the ^{4}He refrigerator at H = 0, 8 and 18 T (using a Cernox 1050 thermometer) or the ^{3}He refrigerator at H = 0 and 8 T (using a Cernox 1010 thermometer).