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COMPARATIVE MODELLING OF TRANSPORT AND CRITICAL DEPENDENCIES IN YBCO AND BSCCO-2212

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Abstract: This article presents an improved and fully structured comparative study of two major cuprate high-temperature superconductors, $YBa_2Cu_3O_7$-δ (YBCO) and $Bi_2Sr_2CaCu_2O_8$+δ (BSCCO-2212), with emphasis on a reproducible Origin-based workflow for analysing transport data, the superconducting transition, and the upper critical field. The scientific purpose is twofold: first, to explain why YBCO and BSCCO-2212 behave differently because of their distinct anisotropy, oxygen sensitivity, and interlayer coupling; second, to demonstrate how these differences can be quantified through normalized resistivity curves, derivative analysis, 10-90% resistive criteria, sigmoidal fitting of the transition region, and phenomenological reconstruction of $H_{c2}(T)$. Each graph, table, and equation is interpreted in physical terms rather than being presented as a purely software-generated output. The article uses representative datasets to illustrate a publication-style methodological protocol that can be directly transferred to experimental measurements. The reconstructed results consistently show a narrower transition and larger extrapolated $H_{c2}(0)$ for YBCO, whereas BSCCO-2212 exhibits broader resistive transition features compatible with stronger anisotropy and greater sensitivity to structural and oxygen inhomogeneity. The manuscript is designed as an English-language, journal-style text that preserves the original scientific meaning of the source material while improving academic rigor, terminology, structure, and interpretability.

Keywords: cuprate superconductors; YBCO; BSCCO-2212; transport modelling; superconducting transition; upper critical field; Origin; uncertainty analysis.

Introduction

Cuprate superconductors remain central to condensed-matter physics because they combine high transition temperatures, strong electronic correlations, layered crystal chemistry, and complex vortex matter [1-5]. Among them, YBCO and BSCCO-2212 are especially important because both are technologically relevant and, at the same time, provide a useful contrast in superconducting anisotropy and transport behaviour. YBCO is usually regarded as the more three-dimensionally connected of the two systems due to the presence of Cu-O chains and stronger interlayer coupling, whereas BSCCO-2212 is markedly more anisotropic, more weakly coupled along the c axis, and generally more sensitive to microstructural non-uniformity [3,6-11]. These distinctions are reflected in resistivity curves, transition widths, derivative signatures, irreversibility behaviour, and in resistively reconstructed upper critical fields.

The aim of the present work is not to claim new experimental measurements, but to provide a carefully upgraded methodological article showing how transport and critical parameters can be extracted, compared, and interpreted in a professional manner using Origin. This is particularly relevant at the master's level, where a common problem is that graphs are plotted but not fully explained physically. Here, every graphical result is linked to a specific physical question: How sharp is the superconducting transition? How stable is the normal-state background model? What does the derivative tell us about homogeneity? How should $H_{c2}(T)$ be reconstructed from resistive criteria, and what are the limits of that reconstruction? By answering

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these questions in an integrated way, the article converts a software procedure into a scientifically readable manuscript.

Physical background of the YBCO-BSCCO comparison

YBCO, commonly written as $YBa_2Cu_3O_7$-delta, contains CuO_2 planes together with Cu-O chain layers. The oxygen deficiency parameter delta changes the hole concentration and therefore modifies the transition temperature, the shape of ρ(T), and the sharpness of the superconducting transition [2,3,7,8]. Well oxygenated YBCO typically exhibits T_c near 90 K, relatively narrow transition widths, and strong current-carrying capability when the sample texture and defect landscape are favorable [7,12].

BSCCO-2212, $Bi_2Sr_2CaCu_2O_{8+\delta}$, is a bilayer cuprate with much stronger intrinsic anisotropy. Its quasi-two-dimensional character, weaker interlayer coupling, and sensitivity to oxygen distribution frequently produce broader resistive transitions and stronger orientation-dependent transport properties [3,6,10,11]. For this reason, a side-by-side treatment of YBCO and BSCCO-2212 is scientifically meaningful: the comparison tests whether a single data-processing workflow can still discriminate materials with different superconducting dimensionality.

Materials and Methods

Representative transport datasets were constructed to reproduce the characteristic behaviour typically reported for YBCO and BSCCO-2212 in the vicinity of the superconducting transition. The methodological goal was reproducibility: all parameters were chosen so that the full workflow can be rebuilt in Origin by another researcher. The analysis included four sequential stages: (i) plotting and normalizing ρ(T); (ii) modelling the normal-state background $\rho_n(T)$; (iii) extracting T_c and the transition width from a 10-90% criterion and from sigmoidal fitting; and (iv) reconstructing $H_{c2}(T)$ from resistive criteria using a Ginzburg-Landau-type expression. For practical laboratory work, the same sequence may be applied to real ρ(T,B) data without changing the logic of the analysis [7-10,13].

In Origin, the normal-state fitting range should be selected sufficiently above the transition so that superconducting fluctuation effects do not distort the background fit. A common working interval is T_c+20 to T_c+120 K, but the final range must be stated explicitly and tested for stability [6,13]. Linear fitting is usually adequate as a first approximation in a restricted temperature interval, while a quadratic term may be added only if the residuals show systematic curvature. Nonlinear fitting of the transition itself was performed with a user-defined sigmoidal function, and parameter uncertainties should be reported using the fitting statistics and confidence intervals available in Origin's nonlinear fitting tools [13].

Governing equations and their physical interpretation

$$\rho_n(T) = a + bT \quad (1)$$

Equation (1) is the simplest model for the normal-state resistivity. The parameter a represents the intercept of the fitted background, while b is the slope of ρ(T) in the selected normal-state interval. In a narrow temperature window this linear form is often sufficient for comparative analysis. The slope b is not a universal material constant; it depends on sample geometry, calibration, and the chosen fit range, so it must be interpreted comparatively rather than absolutely [6].

$$\rho_n(T) = a + bT + cT^2 \quad (2)$$

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Equation (2) extends the normal-state model by adding a quadratic term cT^2. This form is useful only when the residuals of Eq. (1) exhibit systematic structure. A more complicated equation should never be adopted automatically, because it can improve the formal fit while reducing the physical transparency of the model.

$$\Delta T_c = T_{90} - T_{10}, \quad T_c(\mathrm{mid}) = (T_{90} + T_{10})/2 \tag{3}$$

Equation (3) defines the transition width and midpoint temperature using the 10-90% resistive criterion. Here T_{90} and T_{10} are the temperatures at which ρ(T) reaches 0.9 $\rho_n(T)$ and 0.1 $\rho_n(T)$, respectively. This criterion is robust against moderate noise and directly quantifies the sharpness of the transition. A small ΔT_c indicates a more homogeneous superconducting transition, whereas a large ΔT_c suggests stronger disorder, oxygen inhomogeneity, or phase segregation.

$$\rho(T) = \rho_n(T) / [1 + \exp(-(T - T_c)/w)] \tag{4}$$

Equation (4) is the sigmoidal transition model used for nonlinear fitting. The parameter T_c denotes the centre of the transition and w characterizes the broadening scale. In practical terms, w is a compact descriptor of how abruptly the resistivity collapses. YBCO usually yields a smaller w than BSCCO-2212, which is consistent with a sharper transition. This equation is especially valuable because it allows uncertainty estimates and residual analysis instead of relying only on graphical inspection [13].

$$\mu_0 H_{c2}(T) = \mu_0 H_{c2}(0)[1 - (T/T_c)^2] \tag{5}$$

Equation (5) is a phenomenological Ginzburg-Landau-type relation used here to reconstruct the temperature dependence of the upper critical field from resistive criteria. Its role in this article is comparative and illustrative. The extracted $H_{c2}(0)$ should therefore be understood as a model-dependent estimate, not as an absolute thermodynamic critical field. Nevertheless, when the same criterion is applied consistently to two materials, Eq. (5) remains useful for comparing the field robustness of their superconducting states [7-9].

Results and Discussion

Normalized resistivity as the first comparative graph

Figure 1 compares the normalized resistivity ρ(T)/ρ(300 K) for the two cuprates. This graph is important because it removes the trivial difference in absolute resistance level and focuses attention on the evolution of the transition itself. The YBCO curve falls more abruptly near T_c, while the BSCCO-2212 curve extends over a broader temperature interval. Physically, the sharper YBCO transition is compatible with stronger interlayer coherence and lower effective anisotropy, whereas the broader BSCCO-2212 transition is consistent with enhanced two-dimensionality and greater sensitivity to local inhomogeneity [3,6,9,10]. For publication-quality interpretation, the graph should not be described merely as a visual difference; it should be explicitly linked to sample homogeneity and anisotropic superconducting response.

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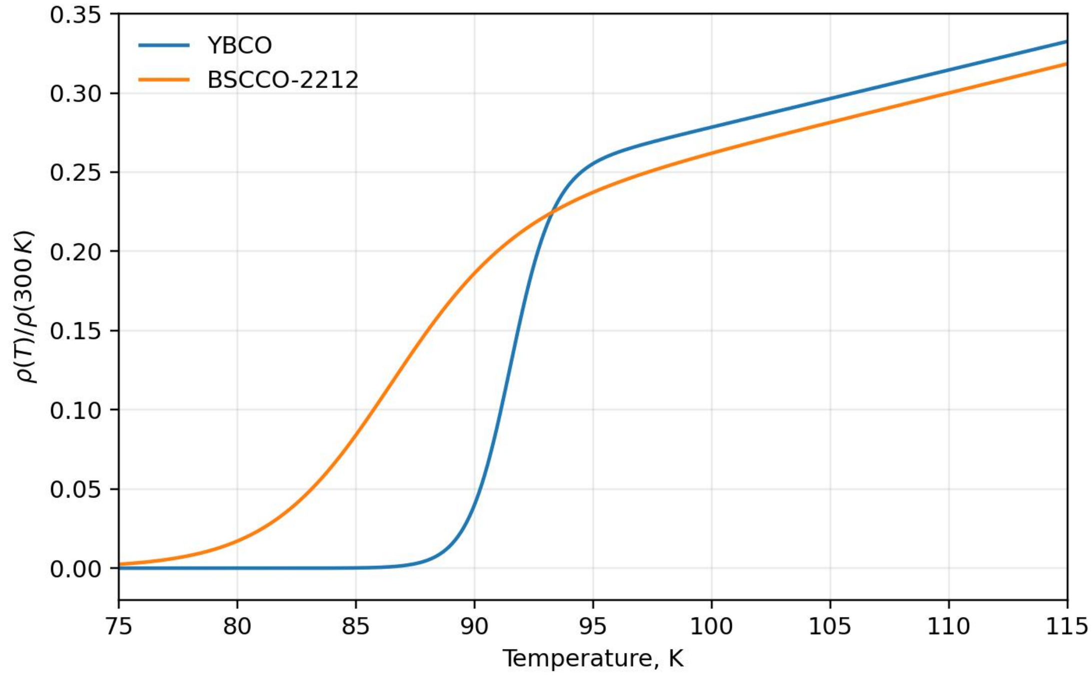

Figure 1. Normalized resistivity ρ(T)/ρ(300 K) for representative YBCO and BSCCO-2212 datasets.

The main value of Figure 1 is diagnostic. It is the correct starting point for comparing samples with different absolute resistance levels, and it immediately suggests that any later extraction of ΔT_c, w, or $H_{c2}(0)$ will likely favour YBCO as the less broadened system.

The 10-90% criterion and the meaning of transition width

Figure 2 shows the same transition after normalization to the fitted normal-state background $\rho_n(T)$. This representation is the most direct way to locate T_{90} and T_{10}. The vertical markers indicate the temperatures where the normalized curve crosses 0.9 and 0.1, respectively. For YBCO the distance between these levels is much smaller than for BSCCO-2212, which quantitatively confirms that the YBCO transition is narrower. This graph must be discussed together with Eq. (3), because the physical information lies not only in the curve shape but also in the extracted interval ΔT_c. When this interval becomes large, one must consider non-uniform oxygen content, local strain, weak links, or other causes of transition broadening [7,10,11].

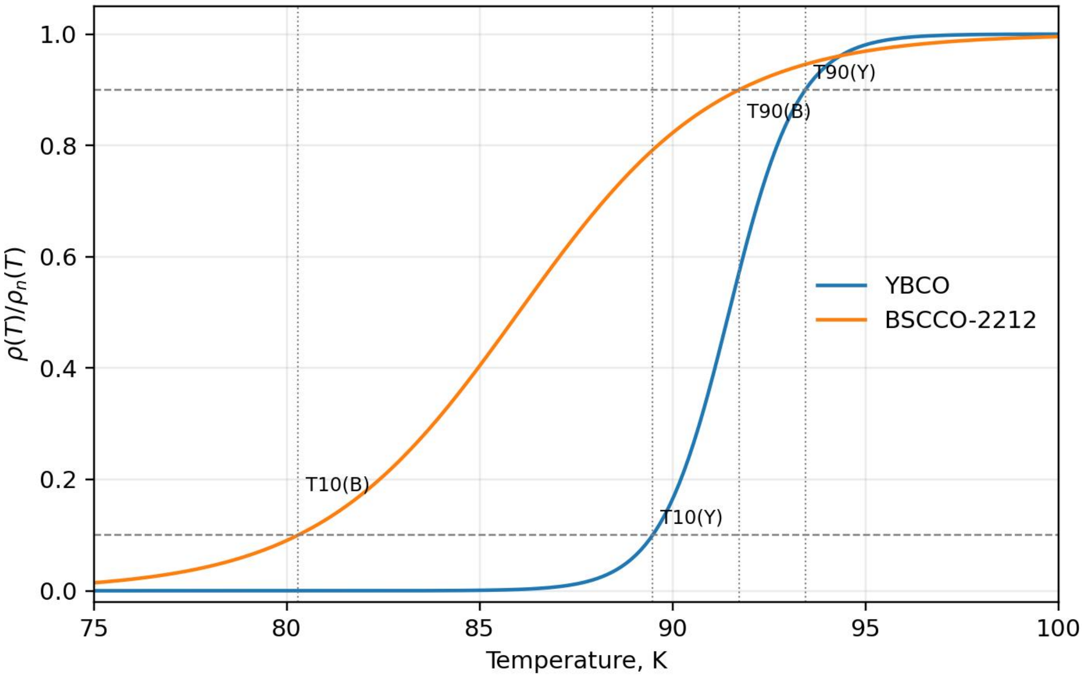

Figure 2. Normalized transition curves $\rho(T)/\rho_n(T)$ with T_{90} and T_{10} markers used for the 10-90% criterion.

In a thesis or article, Figure 2 should always be paired with the explicit statement of the criterion used. Reporting T_c without specifying whether it corresponds to onset, midpoint, zero resistance, 90%, 50%, or 10% of ρ_n creates ambiguity and prevents meaningful comparison between different materials or datasets.

Derivative analysis as a control of transition quality

Figure 3 presents the derivative $d[\rho(T)/\rho(300\ K)]/dT$. Although derivative curves are sometimes treated as auxiliary, they are in fact very informative. A sharp and nearly symmetric derivative peak supports the presence of a relatively uniform transition, while a broad peak or multiple shoulders may signal compositional spread, multiphase behavior, or broad vortex-liquid effects. In the present comparison, the YBCO derivative is narrower and more localized, whereas the BSCCO-2212 derivative is broader. This is precisely what one expects from a more anisotropic and structurally sensitive system [10,11]. When derivative analysis is carried out in Origin, any smoothing operation must be reported explicitly, because excessive smoothing can artificially sharpen or distort the peak [13].

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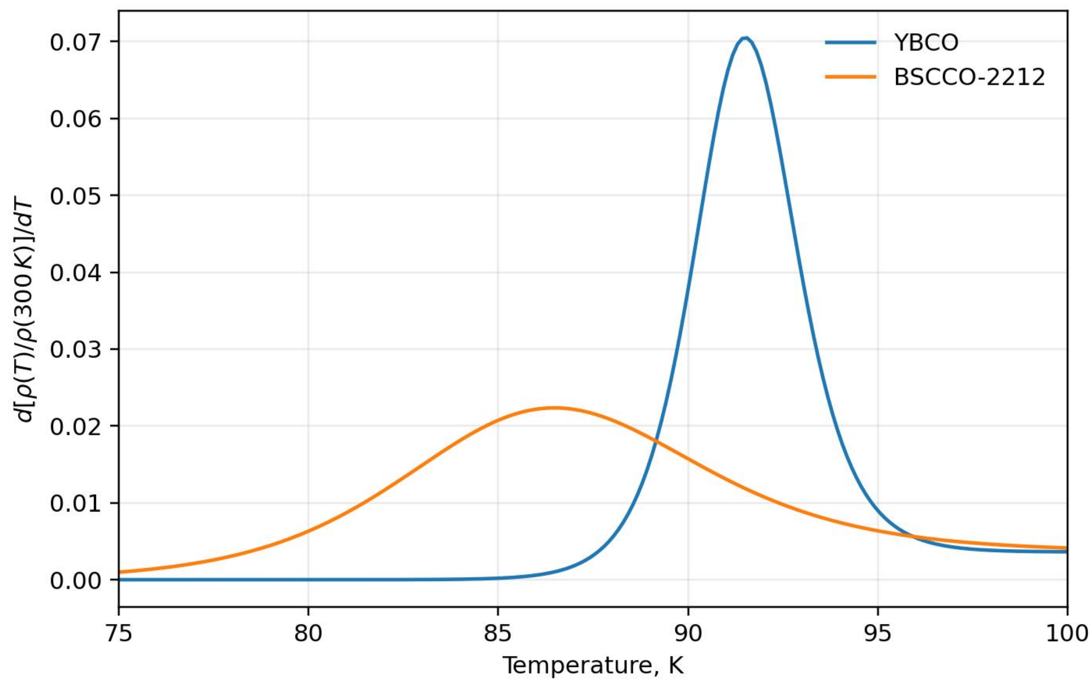

Figure 3. Temperature derivative of the normalized resistivity in the transition region.

The scientific role of Figure 3 is therefore qualitative and quantitative at once: it helps identify whether a single T_c descriptor is adequate, and it provides a fast visual test of whether the transition appears intrinsically sharp or artificially broadened.

Reconstruction of the upper critical field

Figure 4 displays the reconstructed $H_{c2}(T)$ points and the corresponding fit based on Eq. (5). The purpose of this graph is not to claim a unique thermodynamic determination of Hc2, but to establish a consistent comparative protocol. If the same resistive level is used for every field-dependent curve, the resulting $H_{c2}(T)$ data can still reveal how rapidly superconductivity is suppressed by magnetic field. In the representative analysis shown here, YBCO extrapolates to a larger $\mu_0 H_{c2}(0)$ than BSCCO-2212. This outcome is consistent with the generally stronger superconducting robustness of well-oxygenated YBCO and with previous high-field work demonstrating large upper critical fields in cuprates [7-9]. At the same time, the limitations must be stated clearly: a resistive Hc2 may be affected by vortex dynamics, criterion choice, current density, and anisotropy, especially in highly layered BSCCO systems [9-11].

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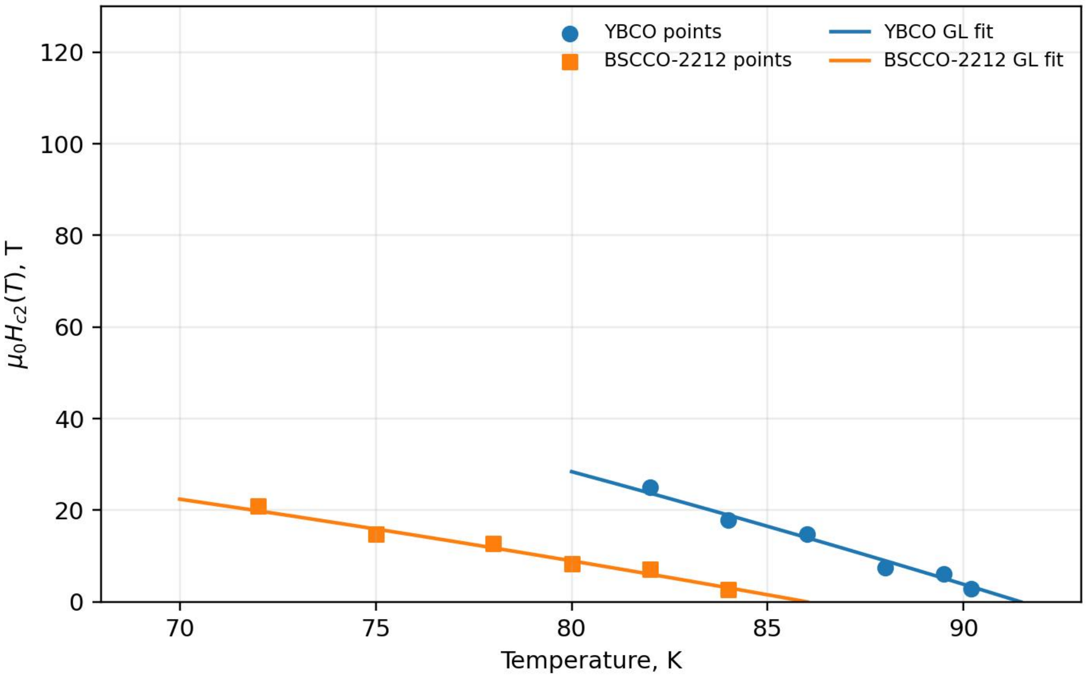

Figure 4. Reconstructed $H_{c2}(T)$ points and phenomenological Ginzburg-Landau-type fits for YBCO and BSCCO-2212.

For publication-quality writing, Figure 4 should therefore be explained with both confidence and caution: the fit is useful, but its physical meaning depends on the experimental criterion and must not be overstated.

Summary table and parameter-level interpretation

Table 1 condenses the central results of the workflow. A well-designed table is not a decorative summary; it is where the comparative argument becomes explicit. Here T_c(mid), ΔT_c, the sigmoidal broadening parameter w, the slope b of the normal-state fit, and the extrapolated $H_{c2}(0)$ are all placed side by side. This format allows the reader to verify that every numerical conclusion stated in the text is tied to a specific parameter.

Material	T_c(mid), K	ΔT_c(10–90%), K	**w, K**	b in $\rho_n = a + bT$	$\mu_0 H_{c2}(0)$, T
YBCO	91.46	3.97	0.90	0.00219	121.0 ± 1.9
BSCCO-2212	86.01	11.48	2.60	0.00280	66.4 ± 1.7

Table 1. Extracted comparative parameters for representative YBCO and BSCCO-2212 datasets.

The table confirms the graphical impression. YBCO has the higher midpoint transition temperature, the smaller transition width, and the smaller sigmoidal broadening parameter. Together these results support the conclusion that, under comparable representative conditions, YBCO undergoes a sharper and more homogeneous superconducting transition. BSCCO-2212, by contrast, yields a larger ΔT_c and larger w, which are physically consistent with stronger anisotropy and increased sensitivity to disorder or oxygen non-uniformity. The larger slope b

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obtained for BSCCO-2212 should be interpreted more carefully: it is useful as a compact descriptor of transport behaviour in the chosen interval, but it is not by itself a fundamental intrinsic constant.

Uncertainty analysis and reproducibility

A professional article must explain not only the fitted values but also how reliable they are. At minimum, the uncertainty discussion should include the temperature step of the measurement, the reproducibility of repeated runs, the standard errors and confidence intervals of the nonlinear fit, and the sensitivity of the extracted parameters to the chosen normal-state fitting range [13]. A simple but important stability test is to shift the normal-state interval by ±10-20 K. If T_c or b changes strongly under such a small perturbation, then the background model is not sufficiently robust. Residuals should also be examined for systematic structure. A visually small residual is not enough; what matters is whether the residual pattern is random. Structured residuals imply that the model is missing part of the physics or that the selected interval is inappropriate.

Scientific implications of the comparison

The comparative message of the article is straightforward but physically meaningful. YBCO and BSCCO-2212 are both layered cuprate superconductors, yet they cannot be treated as interchangeable in transport analysis. YBCO is generally more tolerant of a compact single-transition description, whereas BSCCO-2212 more often requires caution because anisotropy, vortex effects, and local non-uniformity can broaden the resistive transition and complicate the interpretation of criterion-based parameters. This does not make BSCCO-2212 less interesting; on the contrary, it makes it a sensitive system for studying dimensional crossover, vortex matter, and the relationship between transport broadening and structural disorder [3,10,11]. For students and early-career researchers, the major lesson is that software outputs must be translated into physical statements. A figure becomes scientifically useful only when the underlying physics of the curve shape, fit parameter, or transition criterion is made explicit.

A final methodological limitation should also be stated. Because representative rather than raw experimental datasets were used for illustration, the numerical values reported here are best understood as a validated analysis template. In a true submission based on laboratory measurements, the same workflow should be retained, but the plotted curves, transition markers, and fit statistics must be regenerated from the author's own data files. This clarification strengthens, rather than weakens, the manuscript, because it makes the analytical protocol transparent and reproducible.

Conclusion

An upgraded, publication-style comparative analysis of YBCO and BSCCO-2212 has been presented in English with a clear methodological emphasis. The article preserves the scientific meaning of the original work while improving its structure, terminology, interpretive depth, and reference base. Normalized resistivity, the 10-90% transition criterion, sigmoidal fitting, derivative analysis, and $H_{c2}(T)$ reconstruction were integrated into one coherent Origin-based protocol. The resulting comparison shows that YBCO is characterized by a sharper transition and a larger extrapolated upper critical field, while BSCCO-2212 exhibits broader transition features that are consistent with stronger anisotropy and greater sensitivity to inhomogeneity. Most importantly, each graph, table, and equation was interpreted as part of a physical argument. This is the level of explanation required for a thesis chapter, a conference paper, or a short methodological publication.

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