Electromagnetismo cerca del Estado Crítico en Superconductividad de tipo II

A. Badía, C. López, H. S. Ruiz

Departamento de Física de la Materia Condensada
I.C.M.A.–C.S.I.C., Universidad de Zaragoza, ESPAÑA

CAB
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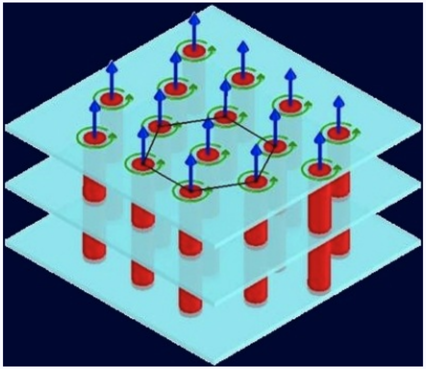
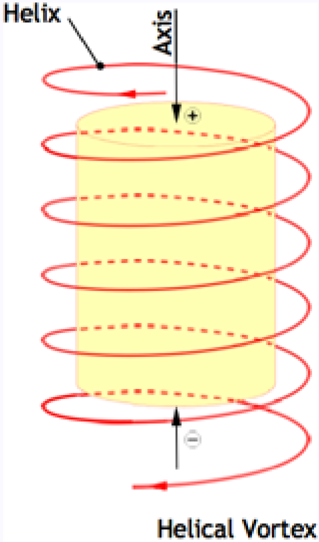
Indice

1. Escenario Electromagnético





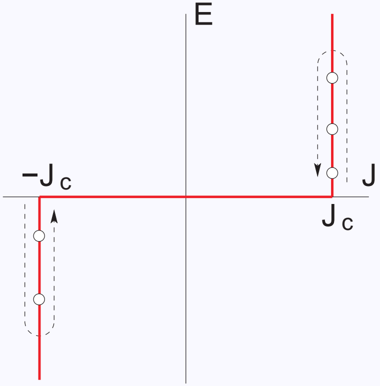
$\Rightarrow$ trabajaremos con campos promedio $\mathbf{B}, \mathbf{E}(\mathbf{J})$

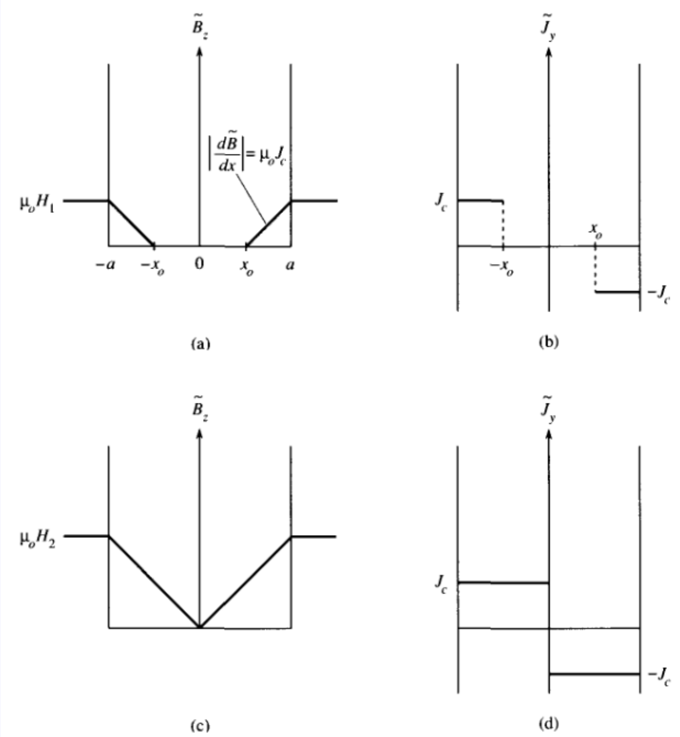
$\rightarrow$ para sistemas con fuerza de anclaje $(\mathbf{F}_p = \mathbf{J} \times \mathbf{B} \Rightarrow \mathbf{J}_c)$

$\star$ en aproximación MQS: $\partial_t \mathbf{E}, \partial_t \rho \approx 0$

$\star$ buscando una formulación *variacional*

El modelo de Estado Crítico





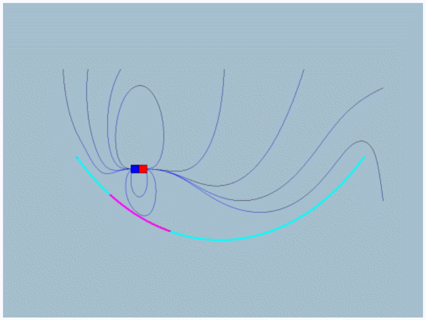
Phys. Rev. Lett. **8** (1962) 250 : Charles P. Bean

En superconductividad tipo-I se conserva la energía

$$-\oint (\mathbf{E}\times\mathbf{H})\cdot d\mathbf{s} = \frac{\partial}{\partial t}\int \frac{B^2}{2\mu_0}dv + \int \mathbf{E}\cdot\mathbf{J}dv$$

$$si \qquad \mathbf{E} = \mu_0\lambda^2\partial_t\mathbf{J} \Rightarrow \mathbf{E}\cdot\mathbf{J} = \frac{d}{dt}(\Lambda J^2/2) \qquad y \ \ldots$$

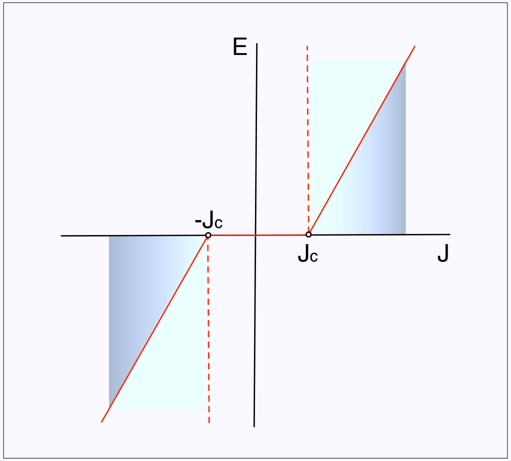
$$\texttt{Min} \quad \frac{1}{2\mu_0}\int_{\mathbb{R}^3}\mathbf{B^2\,dv} + \ \frac{1}{2\mu_0}\int_{v_S}\lambda^2\|\nabla\times\mathbf{B}\|^\mathbf{2}\,\mathbf{dv}$$



$$\mathbf{B} + \lambda^2(\nabla\times\nabla\times\mathbf{B}) = 0$$

Ecuación de London

Para los materiales tipo-II NO se conserva la energía (EM) en situaciones dinámicas (variación de $\mathbf{J}$)



$$\int \mathbf{E}\cdot\mathbf{J}dv \neq \frac{dU}{dt}$$

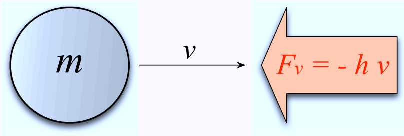
$$\downarrow$$

Existe formulación variacional posible . . . ?

. . .en términos de variables EM si se transfiere energía a otros sectores?

2. Planteamiento matemático

Un sistema mecánico simple irreversible



Lagrangiano Conservativo de una partícula

$$S \equiv \int L(x,v)\,dt = \int \left[\frac{mv^2}{2} - U(x)\right] dt$$

$$\text{Min S} \quad \Rightarrow \quad \frac{d}{dt}\frac{\partial L}{\partial v} - \frac{\partial L}{\partial x} = 0 \quad \Leftrightarrow \quad m\frac{dv}{dt} = -\frac{\partial U}{\partial x} \equiv F_{cons}$$

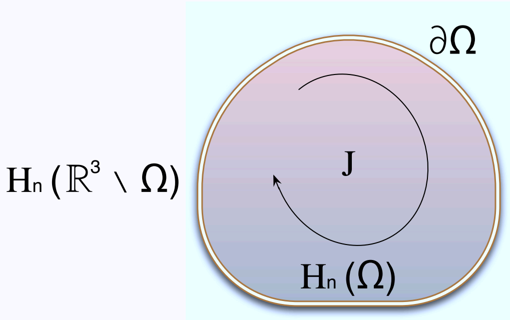
Lagrangiano modificado

$$\hat{S} \equiv \int dt \hat{L}(x,v,t) \quad \text{with} \quad \hat{L} \equiv L + \left[-\int_0^v F_v\,dv\right] t$$

$$\text{Min } \hat{S} \quad \Rightarrow \quad \frac{d}{dt}\frac{\partial \hat{L}}{\partial v} - \frac{\partial \hat{L}}{\partial x} = 0 \quad \Leftrightarrow \quad m\frac{dv}{dt} = -\frac{\partial U}{\partial x} - hv = F_{cons} + F_{visc}$$

$\star$ Las variaciones de F_v son despreciables en $[0,t]$ $\star$ (invariante adiabático)

Problema electromagnético Irreversible (MQS)



$$\texttt{Minimizar} \quad \mathcal{C} \equiv \frac{\mu_0}{2} \int_{\mathbb{R}^3} \|\mathbf{H}_{n+1} - \mathbf{H}_n\|^2 + \Delta t \int_\Omega \int_0^J E(J)$$

$$\Updownarrow \quad (\mathbf{E} = \rho \mathbf{J} \quad \text{o bien} \quad F_{diss} = \frac{\rho J^2}{2})$$

$$\left(\mu_0 \frac{\partial}{\partial t} - \rho \nabla^2\right) \mathbf{H} = 0$$

Ecuación de difusión magnética en un metal

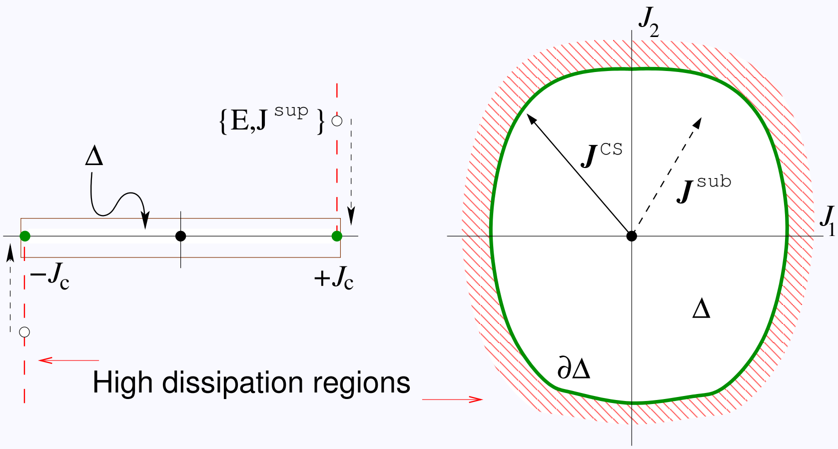
El problema del Estado Crítico en superconductividad

$$\texttt{Minimizar} \quad \mathcal{C} \equiv \frac{\mu_0}{2}\int_{\mathbb{R}^3} \|\mathbf{H}_{n+1} - \mathbf{H}_n\|^2 \quad \texttt{para} \quad \mathbf{J} \in \Delta$$

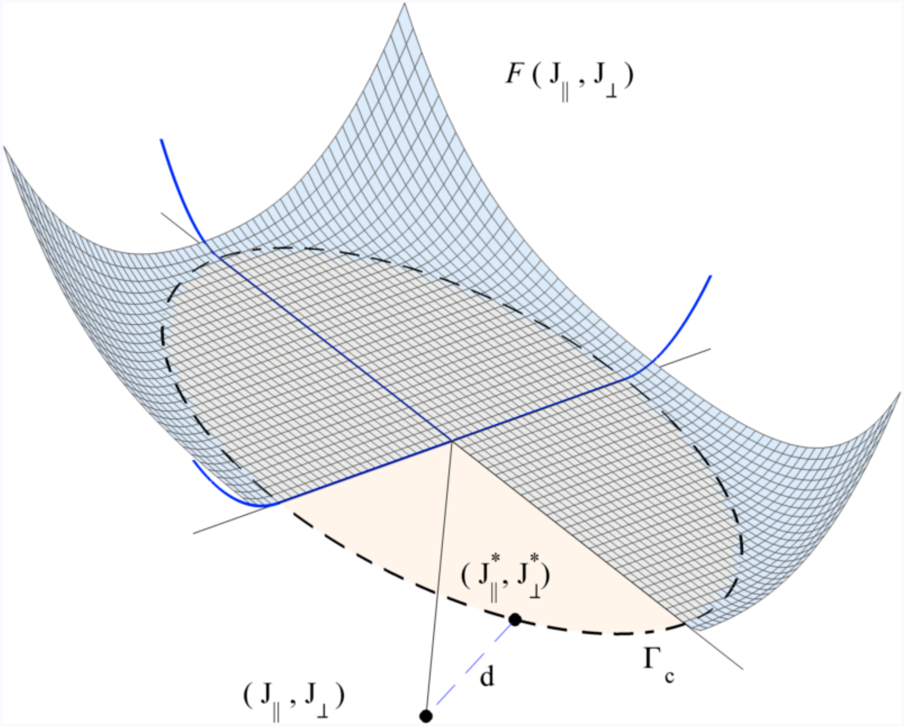
$$\Downarrow$$

$$\mathbf{J} \in \partial\Delta$$

ESTADO CRITICO general



Más allá del Estado Crítico en superconductividad: el formalismo de la función de disipación



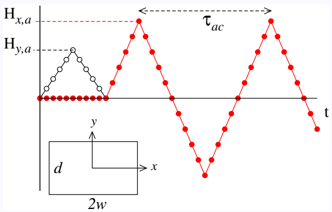
arXiv:1204.2682 Badía & López

3. Problemas Físicos

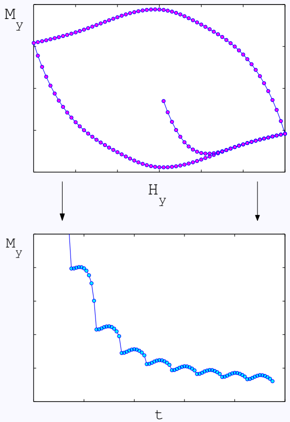
3.1. Estado crítico: *flux shaking* (CAB - 2008)

7. Perspectivas

7.1. Simulación del caso paramagnético



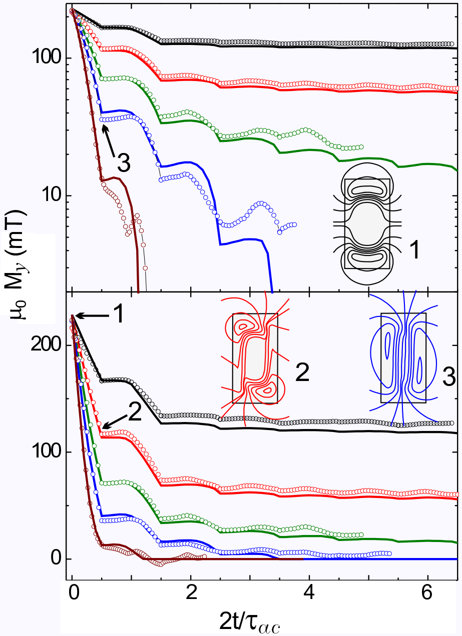
Influencia de la dependencia $J_{c\perp}(H)$

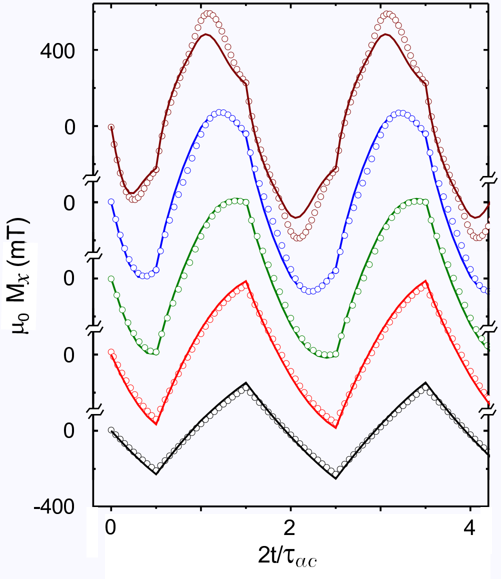


$$J_{c\perp}\left(\vec{h}_{\mathrm{n+1}}\right) \leftarrow J_{c\perp}\left(\vec{h}_{\mathrm{n}}\right)$$
$$\Downarrow \qquad\qquad \uparrow$$
$$\{\zeta_{\mathrm{i,n+1}}\} \rightarrow \vec{h}_{\mathrm{n+1}}$$

Ejemplo 1: teoría vs. experimento

Experimentos en MgB_2



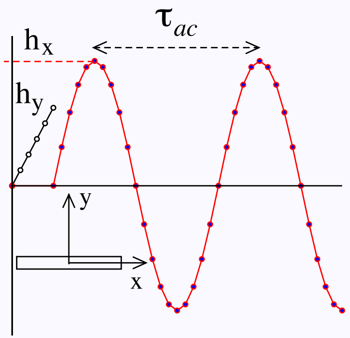


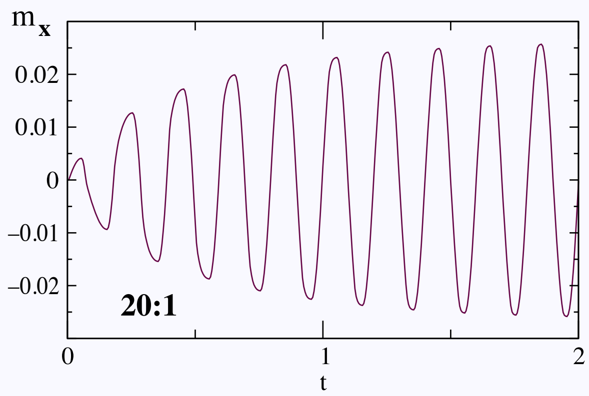
Supercond. Sci. Technol. **22** (2009) 015021:

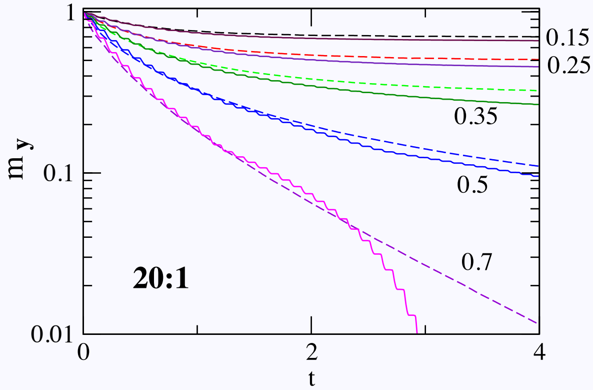
Luzuriaga, Badía, Nieva, Giordano, López, Serquis, Serrano

Ejemplo 1: nuevos efectos

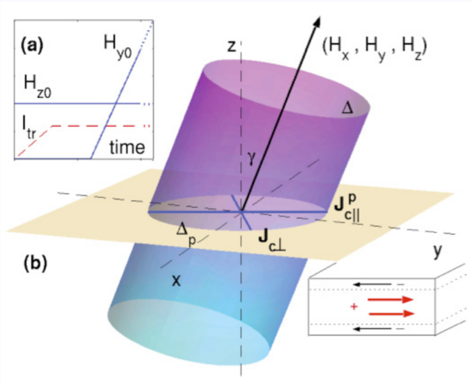
Escala de tiempo "Dimensional" $\left(\tau_0 \equiv \dfrac{\tau_{ac} w}{2d}\right)$

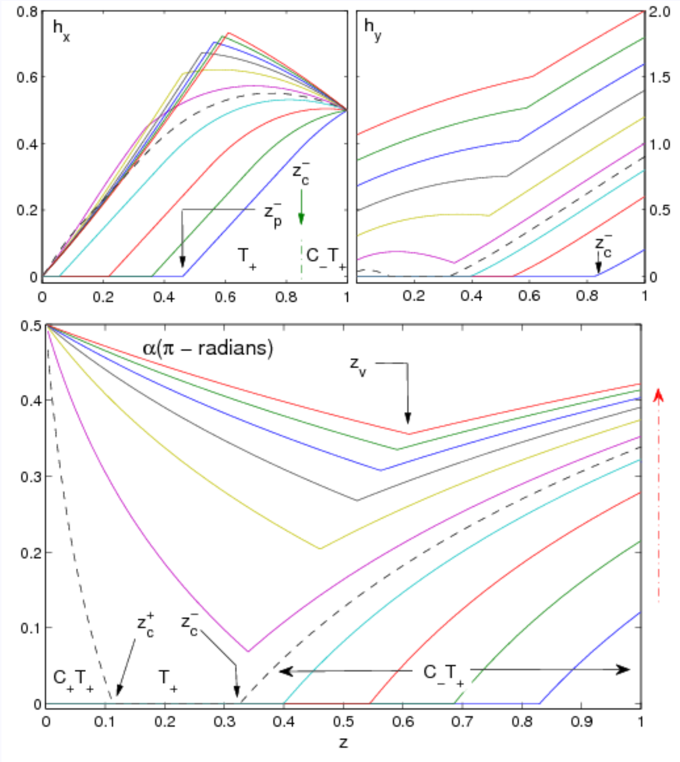






3.2. Estado crítico: *resistencia negativa?*





Phys. Rev. B **83** (2011) 014506: Ruiz, Badía, López

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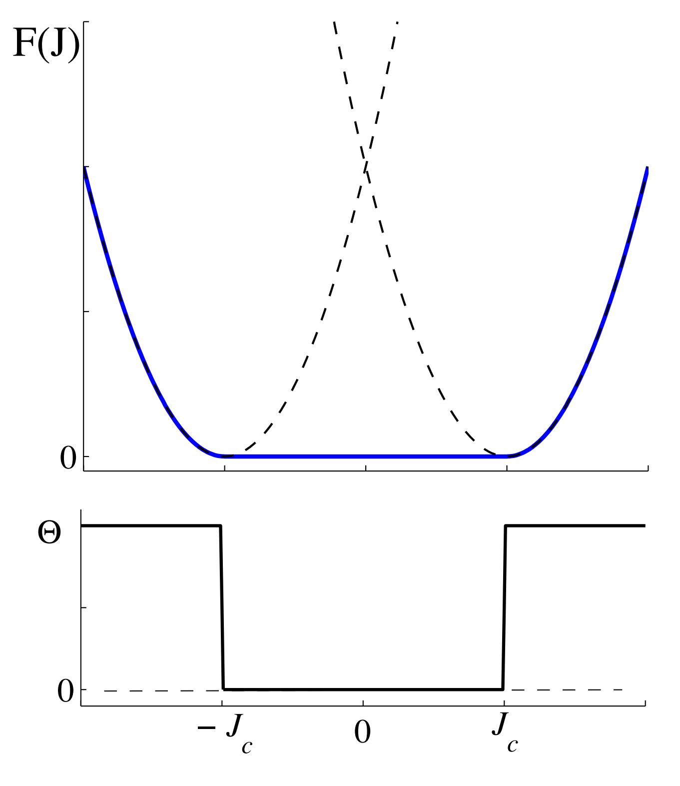
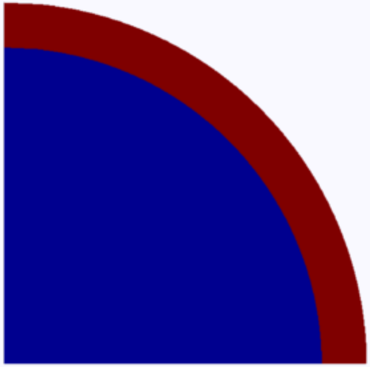
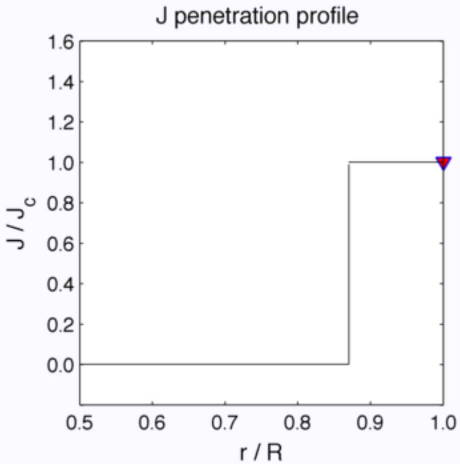
3.3. Sobre el estado crítico: *disipación en tipo-II*

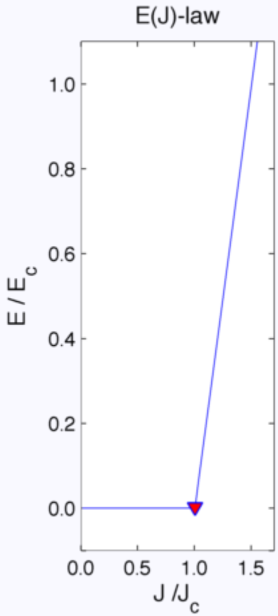
$$\texttt{Minimizar}\quad \mathcal{C} \equiv \frac{\mu_0}{2}\int_{\mathbb{R}^3} \|\mathbf{H}_{n+1} - \mathbf{H}_n\|^2 + \Delta t \int_{\Omega} \mathcal{F}[J]$$



El problema de la conductividad en materiales tipo-II







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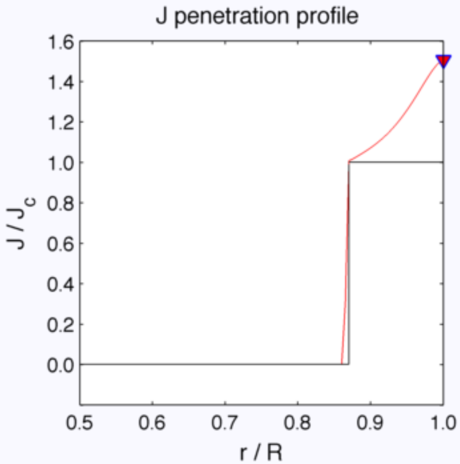

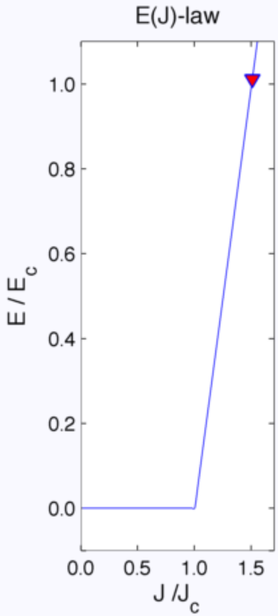

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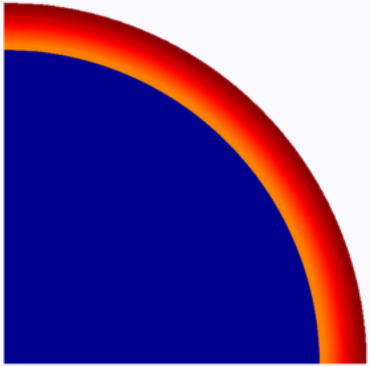

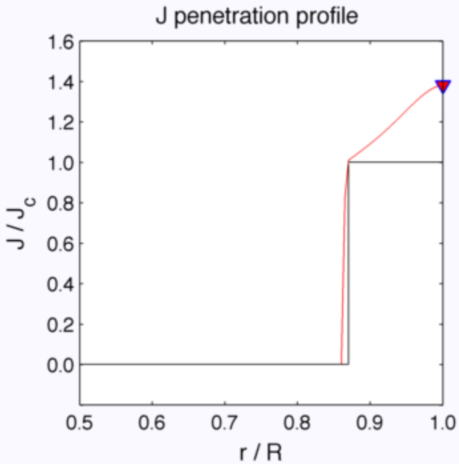

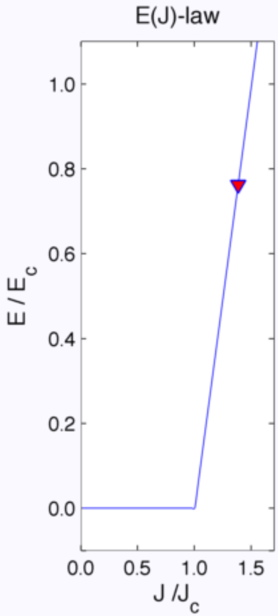

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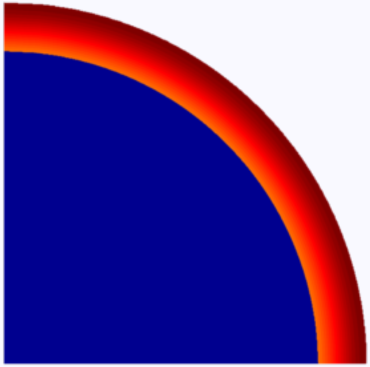

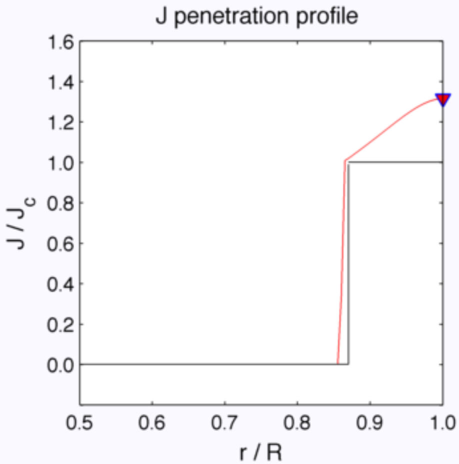

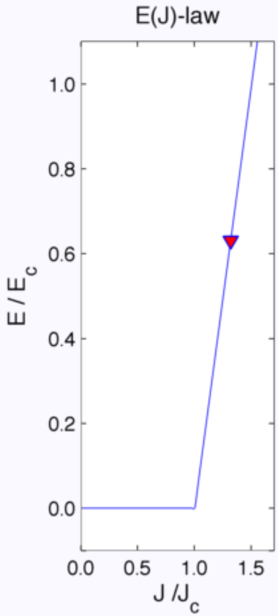

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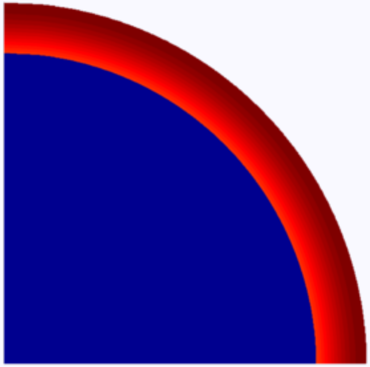
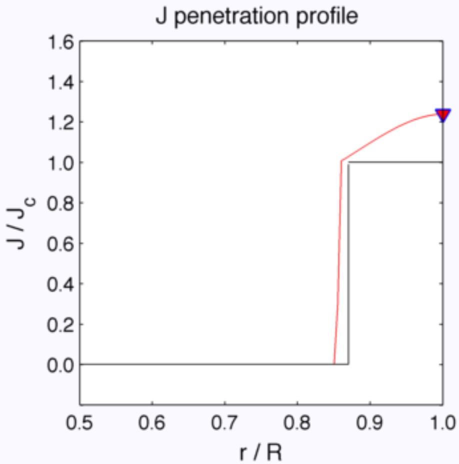
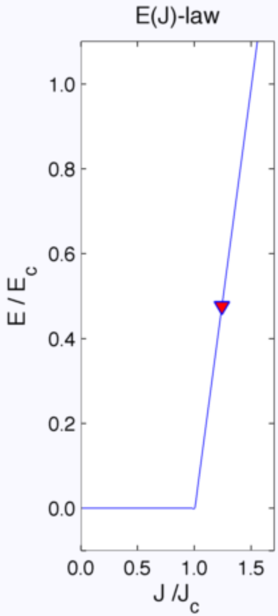
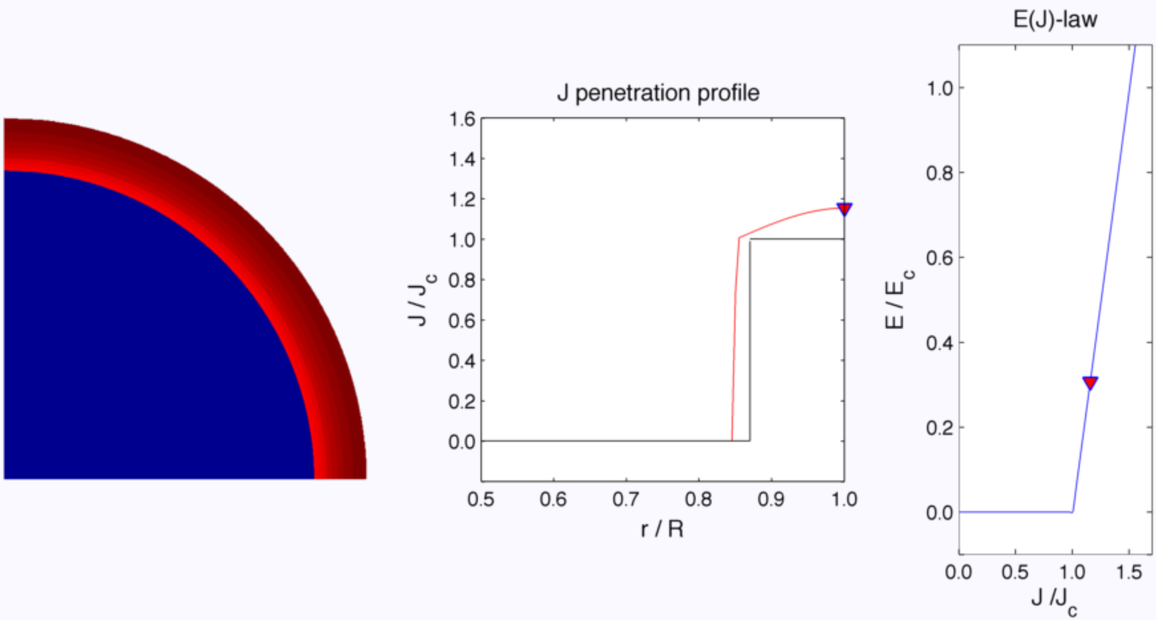
El problema de la conductividad en materiales tipo-II



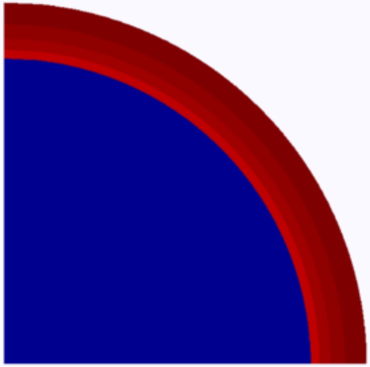


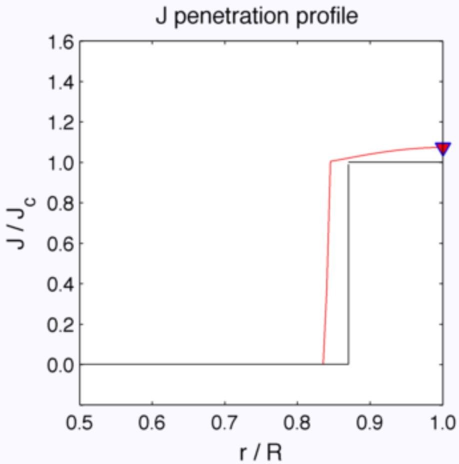


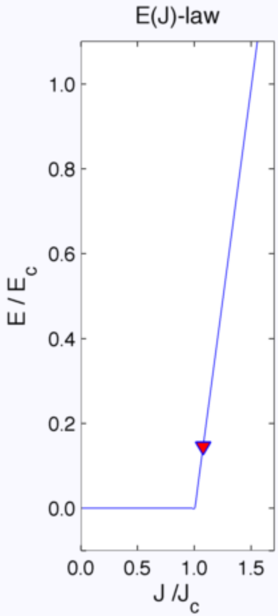
El problema de la conductividad en materiales tipo-II



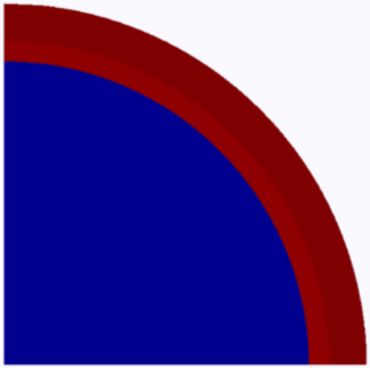
El problema de la conductividad en materiales tipo-II

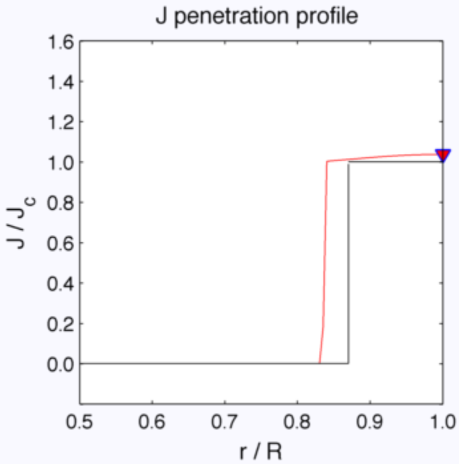


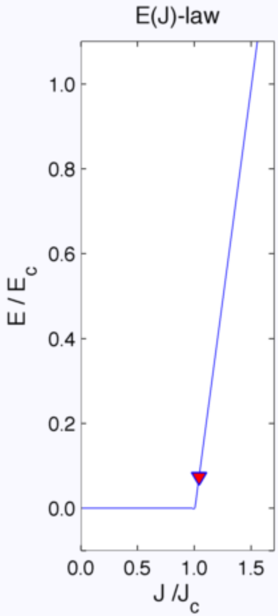




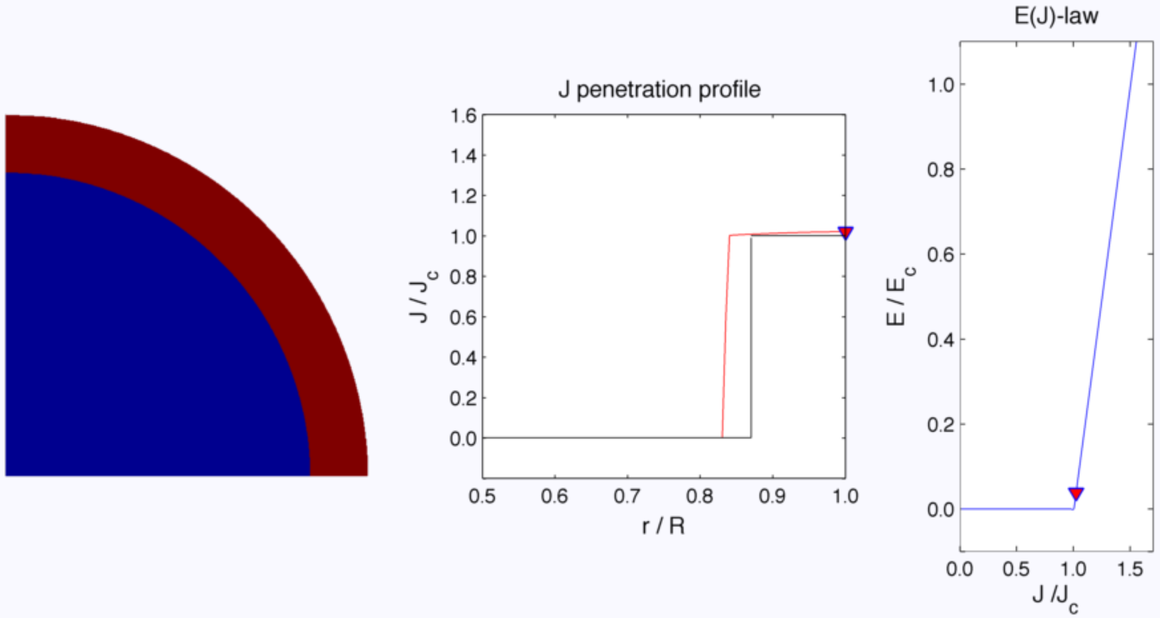
El problema de la *conductividad* *en materiales tipo-II*



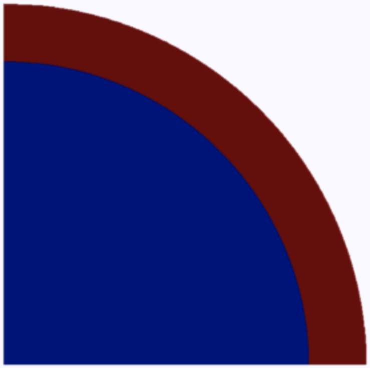


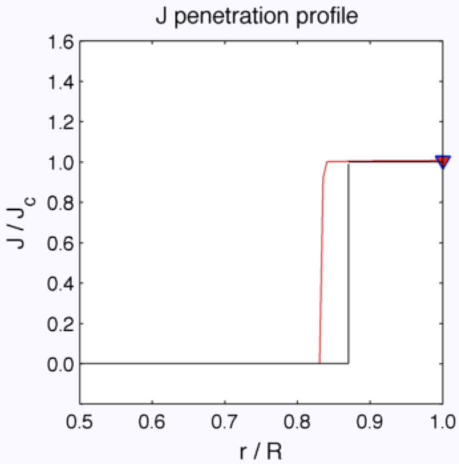


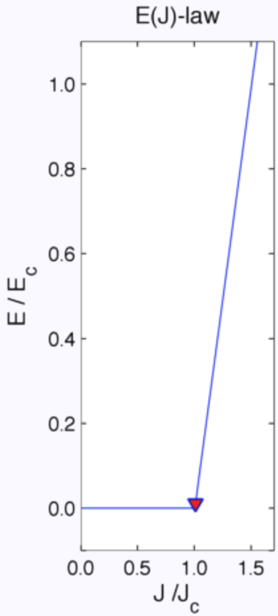
El problema de la conductividad en materiales tipo-II



El problema de la conductividad en materiales tipo-II



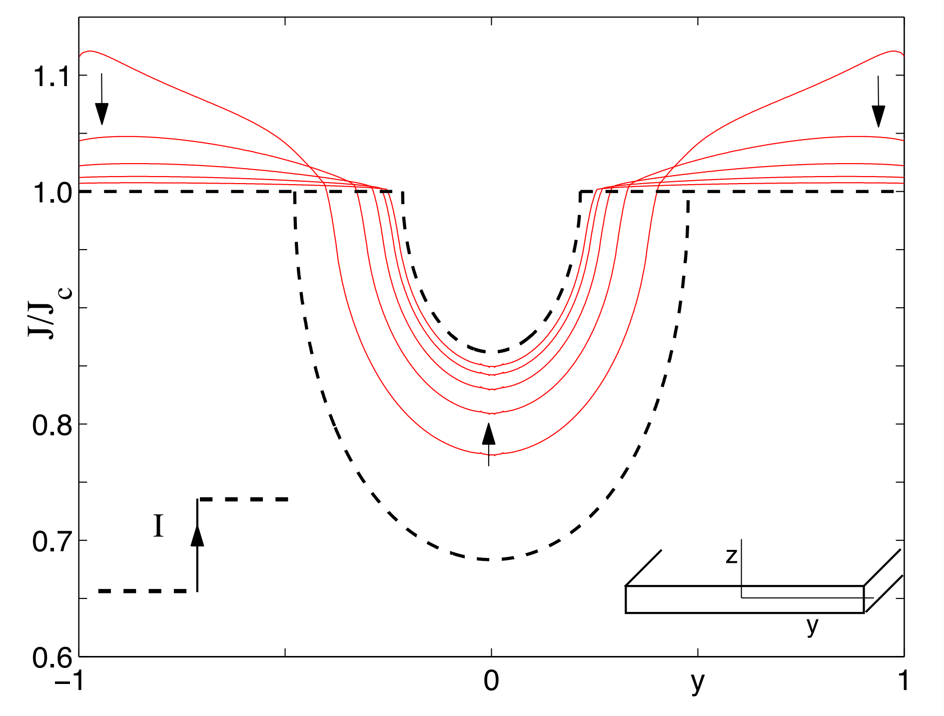




Difusión hacia el Estado Crítico en cintas superconductoras tipo-II

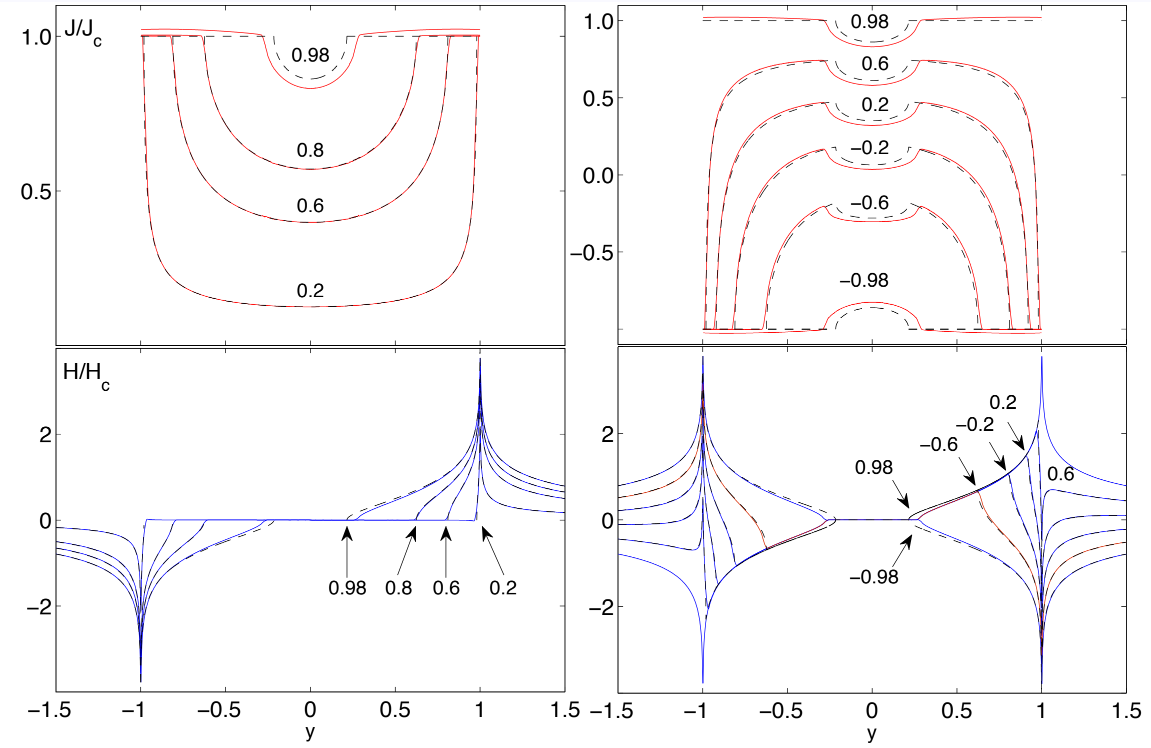
arXiv:1204.2682 Badía & López

Phys. Rev. B **48** (1993) 12893: Brandt & Indenbom



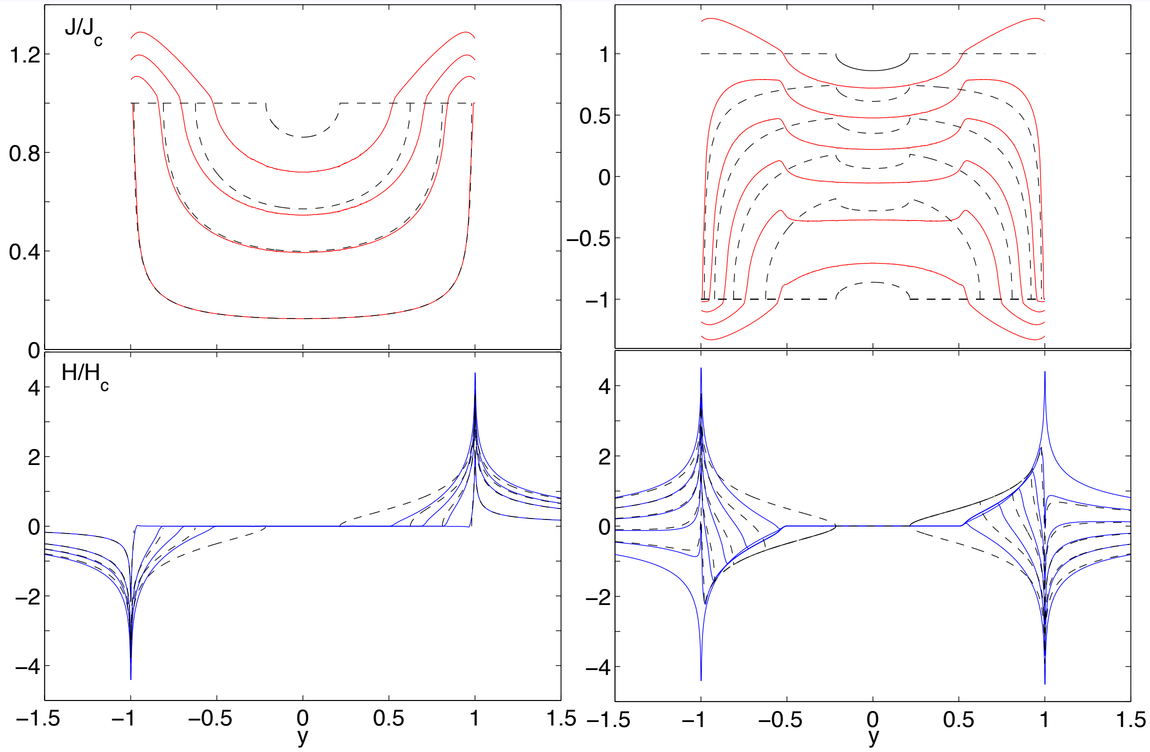
Experimento de transporte en cintas tipo-II

$$\tau_0/\tau_\rho = 2$$



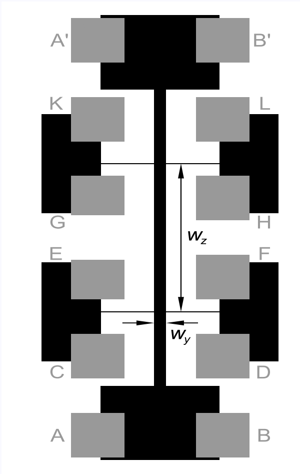
Experimento de transporte en cintas tipo-II

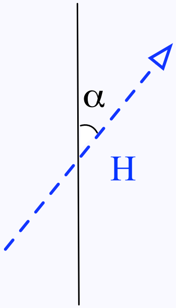
$$\tau_0/\tau_\rho = 0.2$$

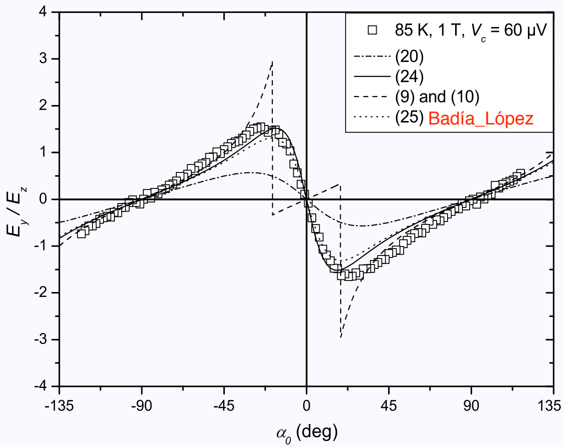


Problemas en marcha

Supercond. Sci. Technol. 24 (2011) 062002: Clem, Weigand, Durrell, Campbell



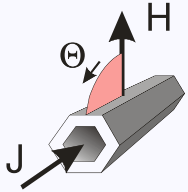




Problemas en marcha ...

M. L. Amigó, G.Nieva

Como se ve en la última figura (fig6) la disipación es mayor cuando J//H, es decir en la situación en que la fuerza de Lorentz debiera ser cero para los vórtices en la dirección del campo. Si hay cortes de vórtices debiera haber líneas de flujo que en forma efectiva estarían transversales al campo y se moverían disipando. Porque disipan más? En parte se puede atribuir a la anisotropía electrónica pero no todo. El coeficiente de anisotropía que sacamos de otras mediciones es ~1.2, (como máximo ~1.8).



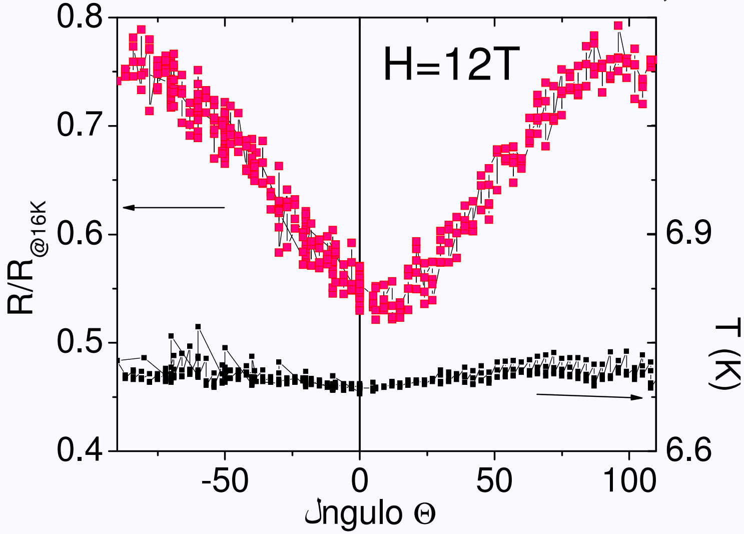
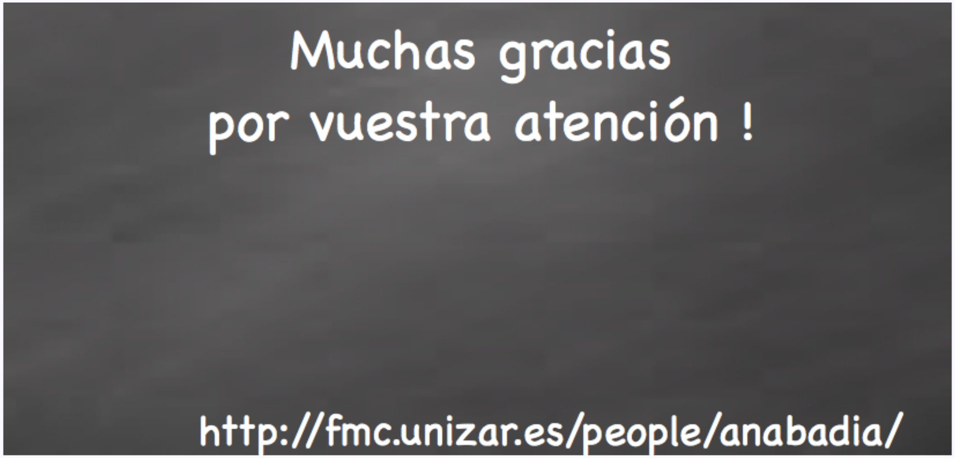


Fig7


Muchas gracias
por vuestra atención !
http://fmc.unizar.es/people/anabadia/