

Confinement of the superconducting order parameter in superconductor-ferromagnet hybrids

Werner Gillijns (INPAC)

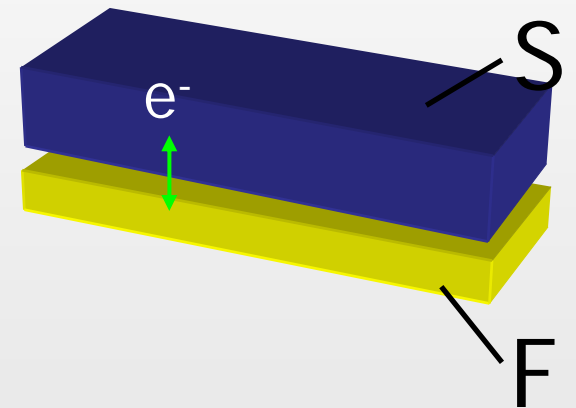
Collaborators:

- Dr. Alejandro Silhanek (INPAC)
- Dr. Alexei Aladyshkin (INPAC)
- Prof. Victor Moshchalkov (INPAC)

Introduction: Superconductor-Ferromagnet hybrids

Interaction between superconductor (S) and ferromagnet (F):

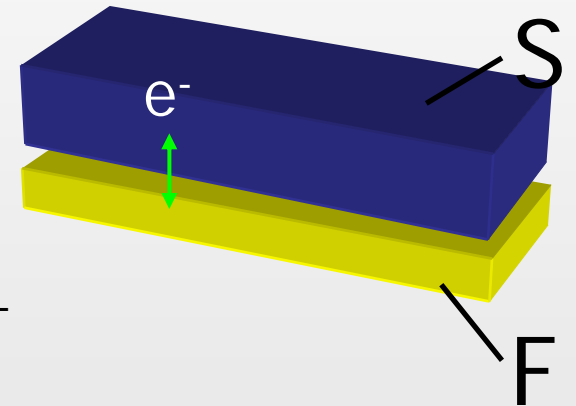
1. Exchange interaction via the proximity effect
(spin valve, π -junctions,...)



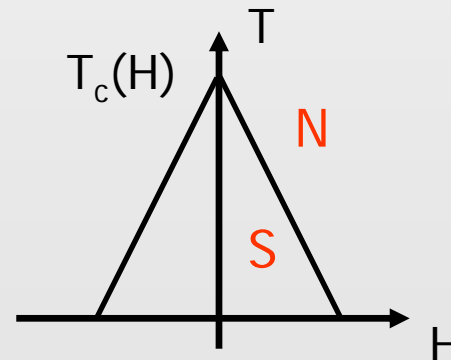
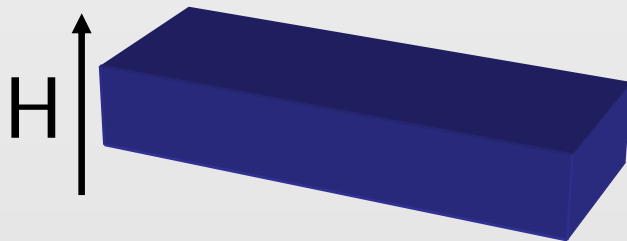
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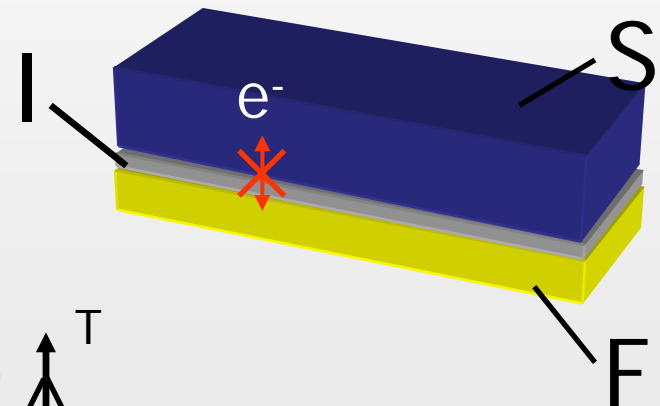
2. Electromagnetic interaction



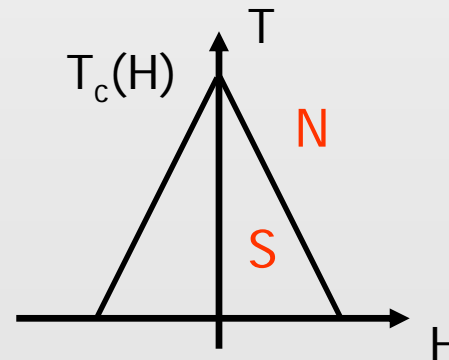
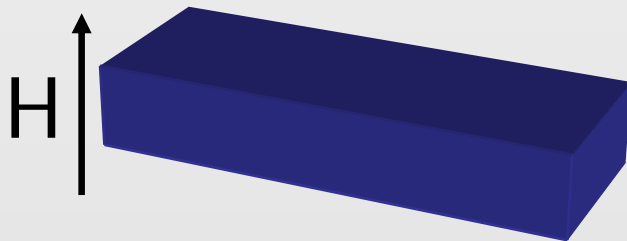
Introduction: Superconductor-Ferromagnet hybrids

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Introduction: Superconductor-Ferromagnet hybrids

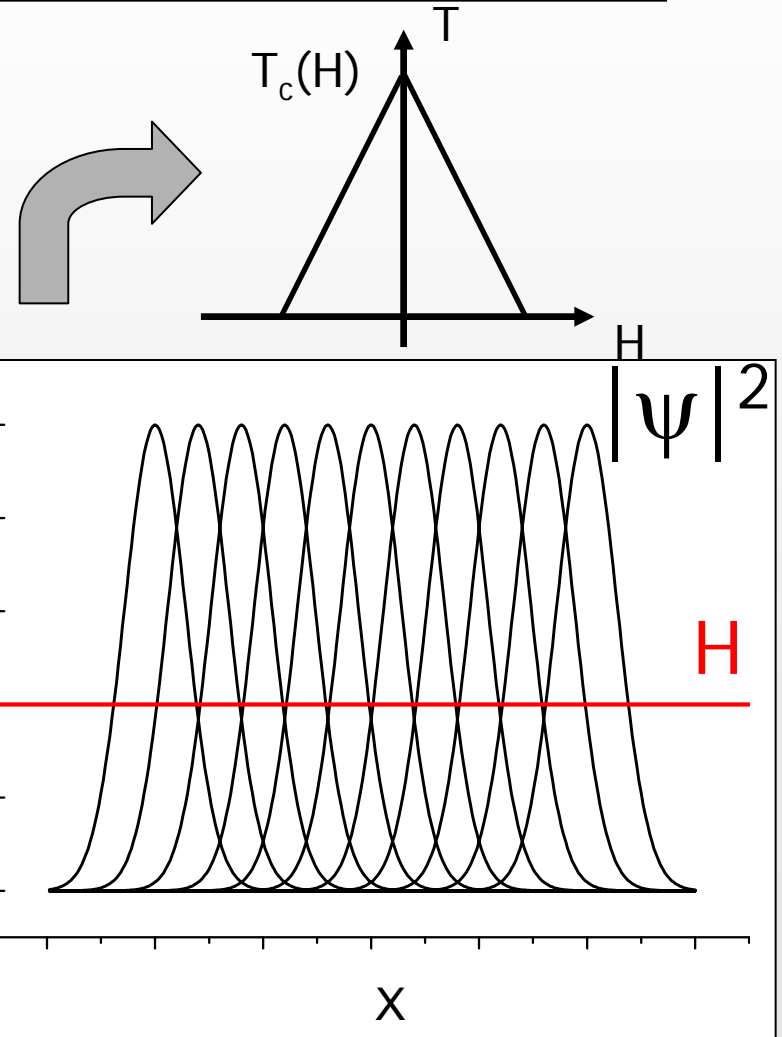
Linearized Ginzburg-Landau:

$$-\left(\nabla + \frac{2\pi i}{\Phi_0} \mathbf{A}\right)^2 \Psi = \frac{1}{\xi^2(T)} \Psi$$

1. Uniform field

$T_c(H)$ independent on position

Wavefunction is uniform over space



Introduction: Superconductor-Ferromagnet hybrids

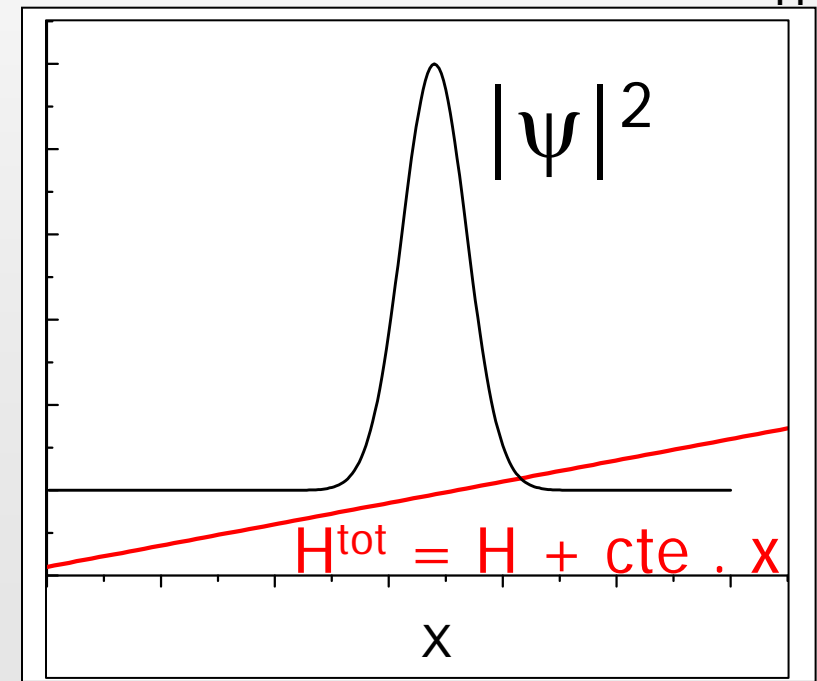
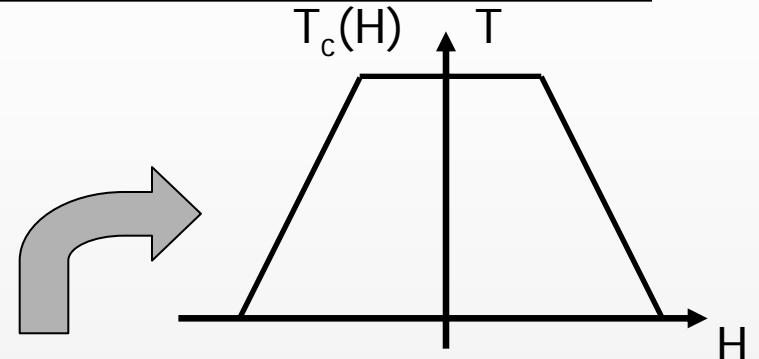
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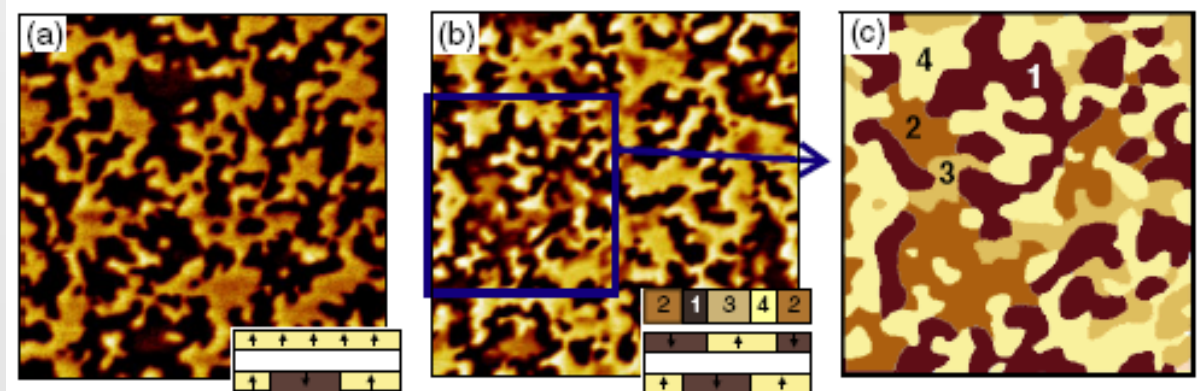
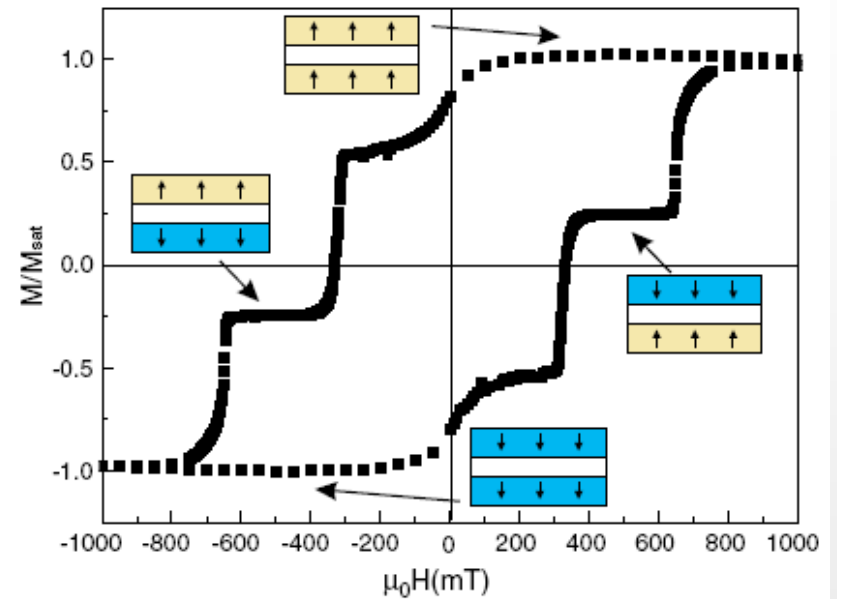
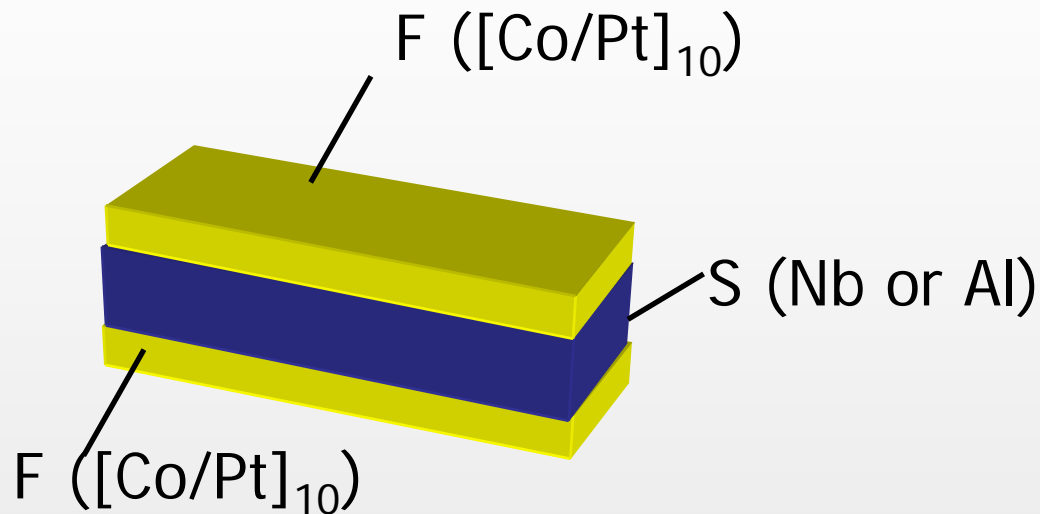
2. Non-uniform field

$T_c(H)$ is position dependent

Wavefunction is localized in space

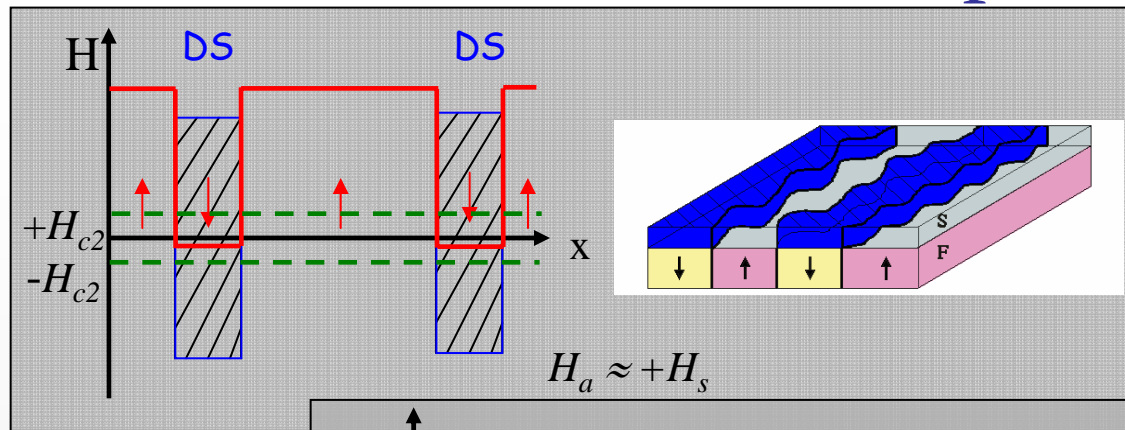


Sample characterization

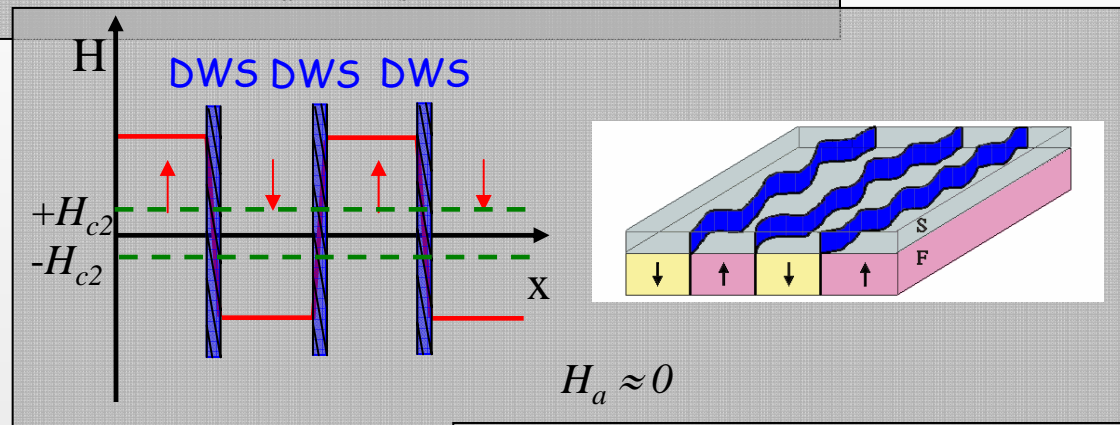


W. Gillijns et al.,
Phys. Rev. Lett. **95**, 227003 (2005)

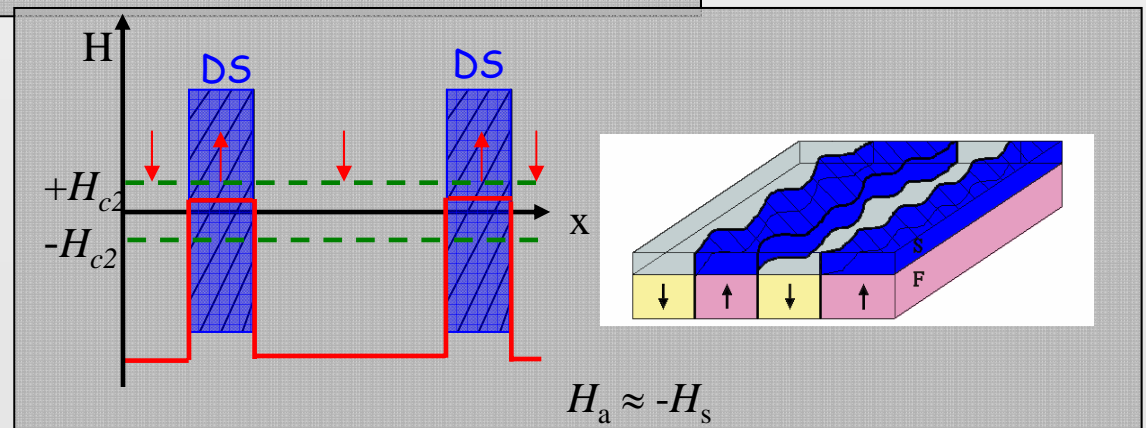
Domain wall superconductivity



$H > 0$



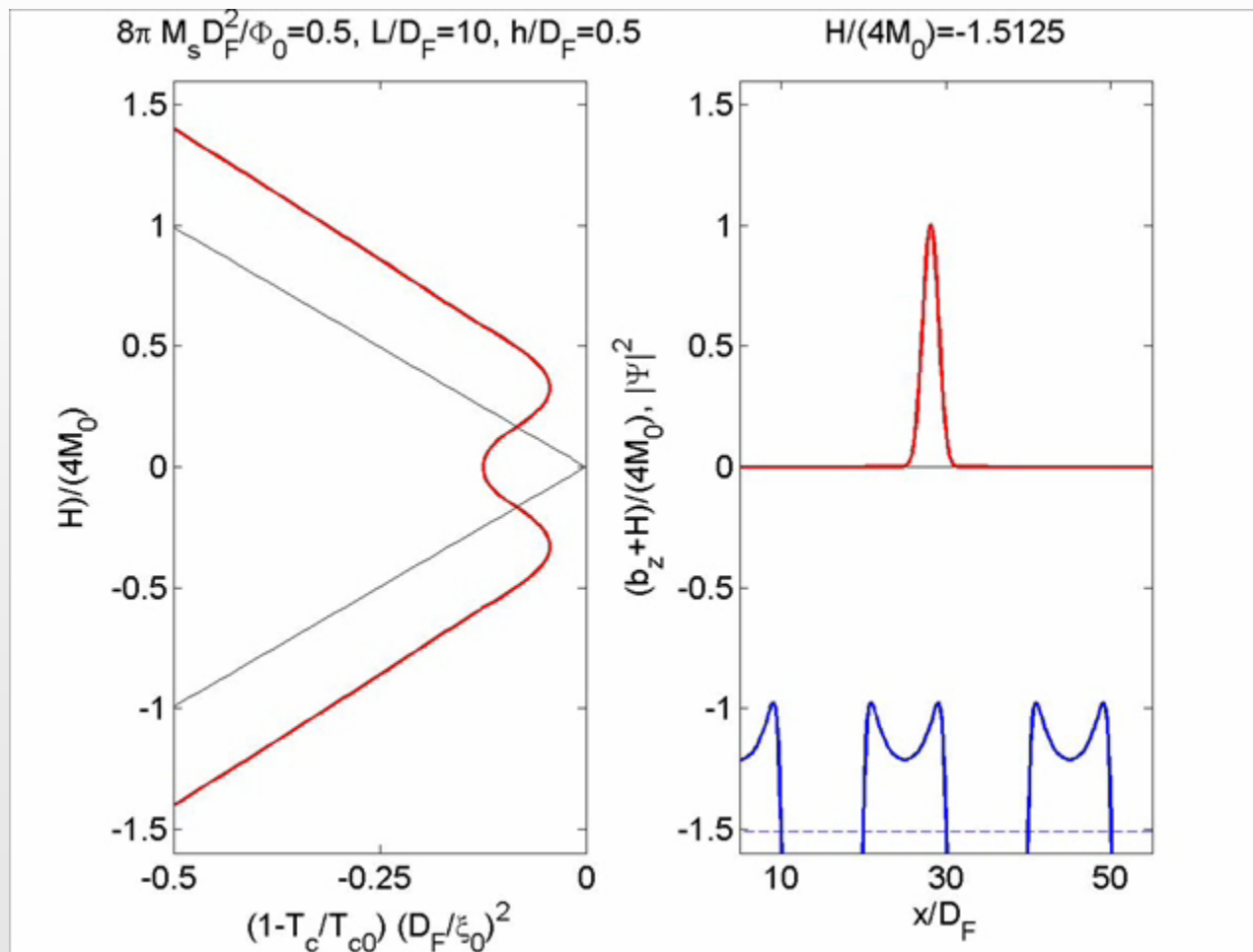
$H = 0$



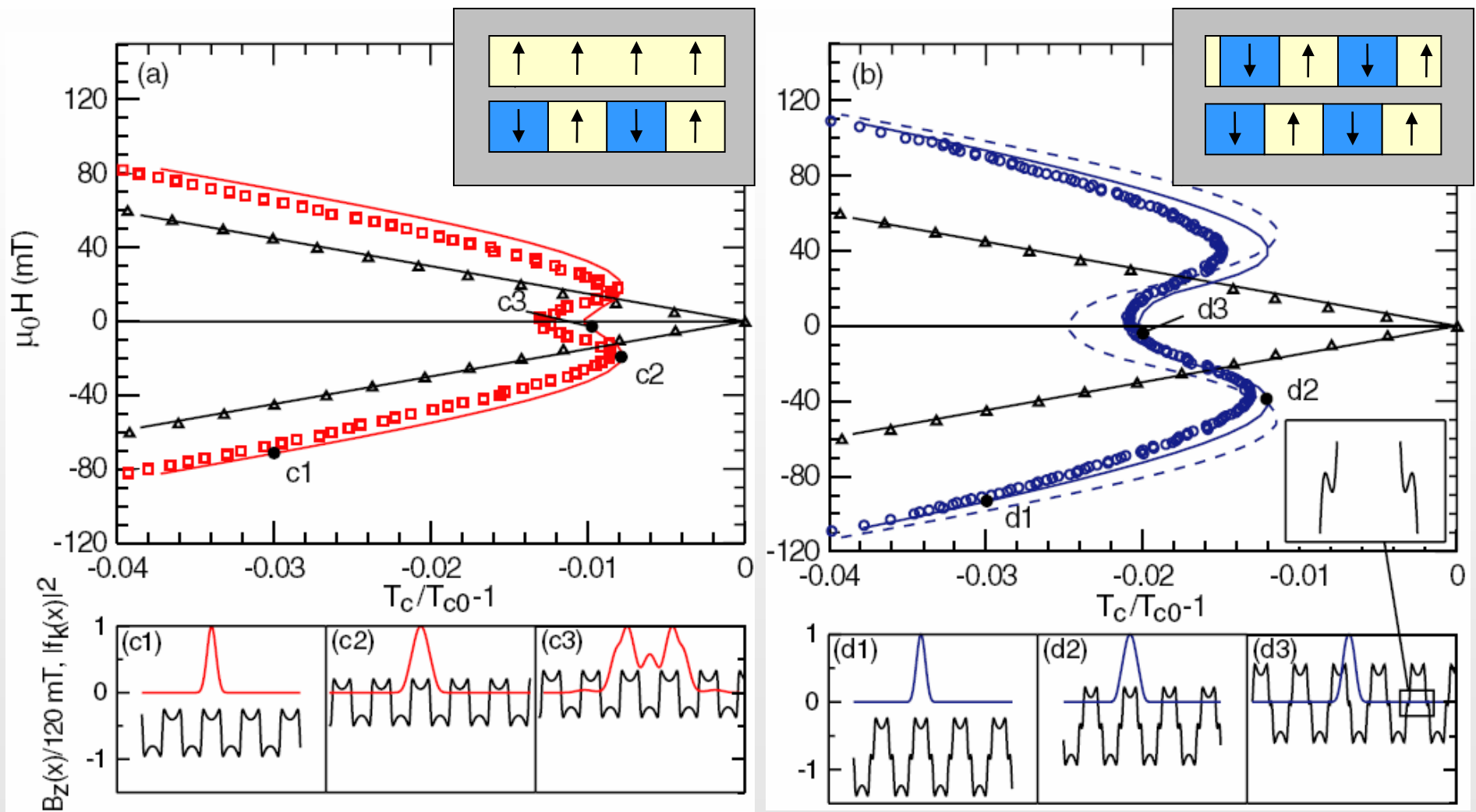
$H < 0$

Z. Yang, . M. Lange, A. Volodin, R. Szymczak, V. V. Moshchalkov, *Nat. Mat.* **3**, 793 (2004)

Nucleation of SC in a S/F hybrid

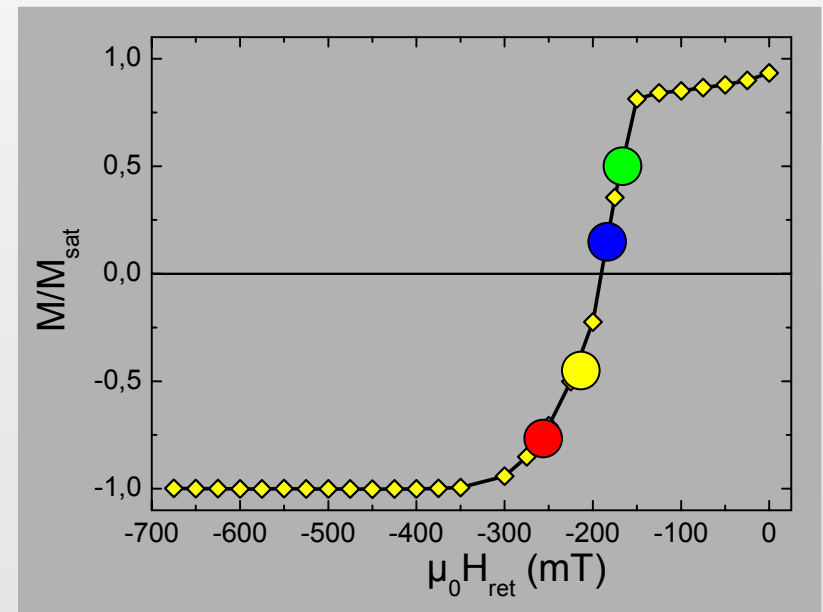
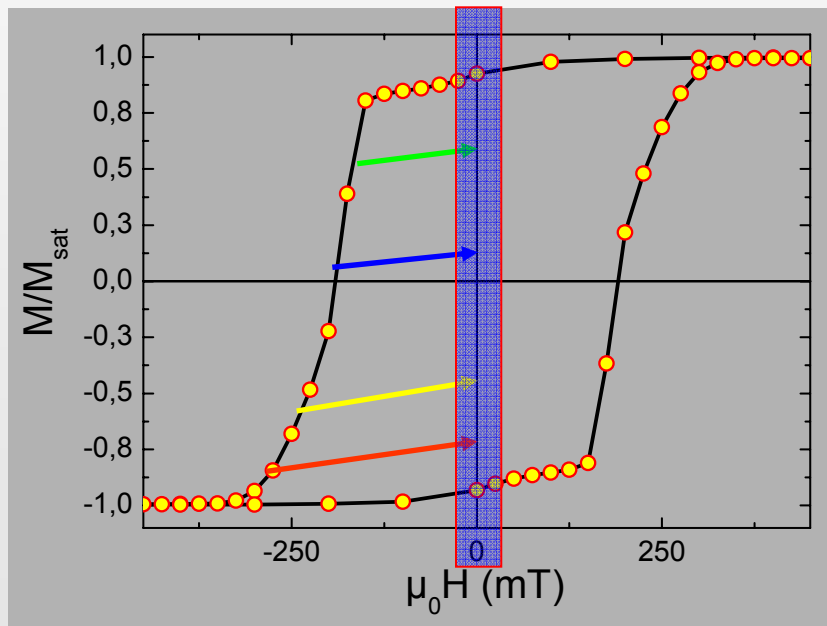
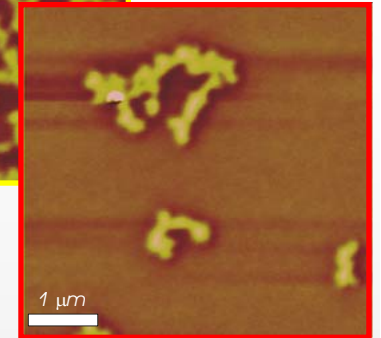
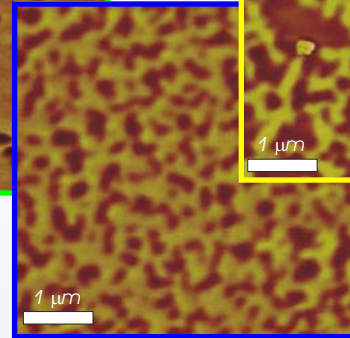
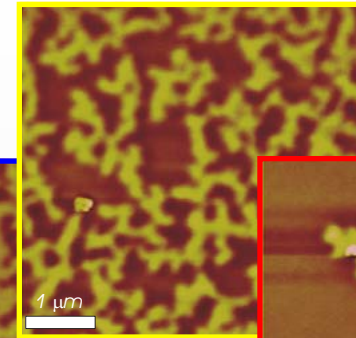
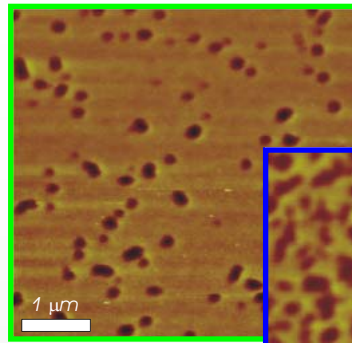
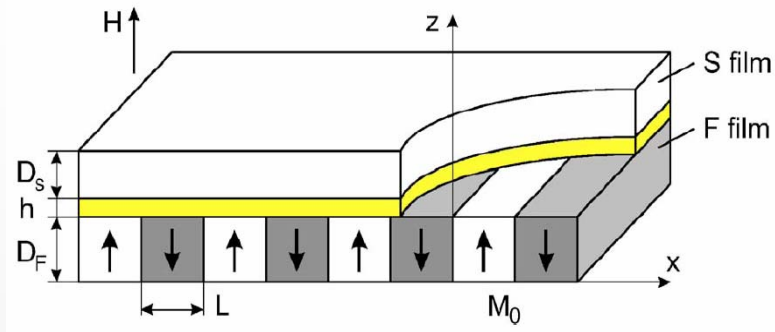


Amplitude of modulated magnetic field



W. Gillijns et al., *Phys. Rev. Lett.* **95**, 227003 (2005)

Sample characterization II



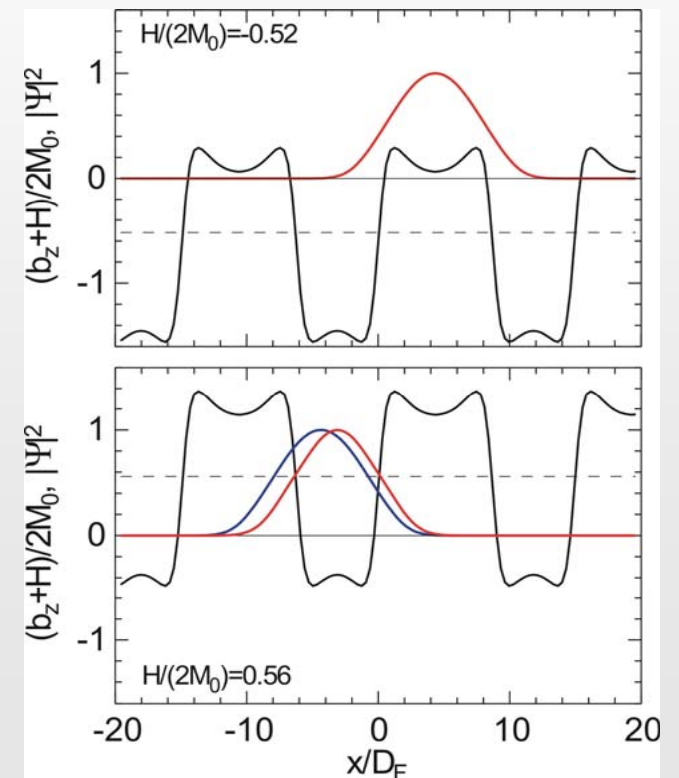
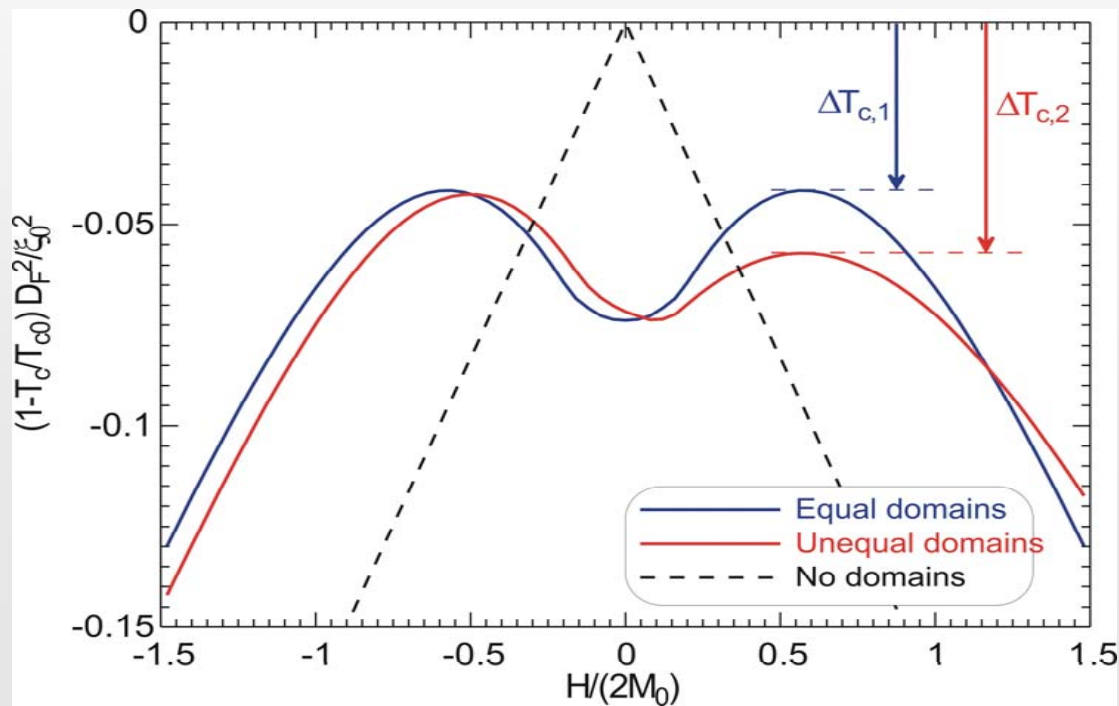
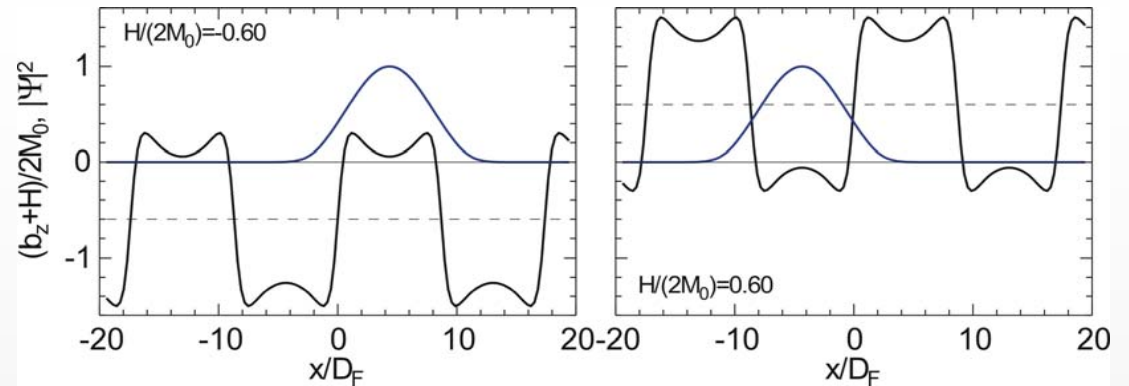
W. Gillijns et al., PRB(R) 76, 060503 (2007)

Quantum confinement effect

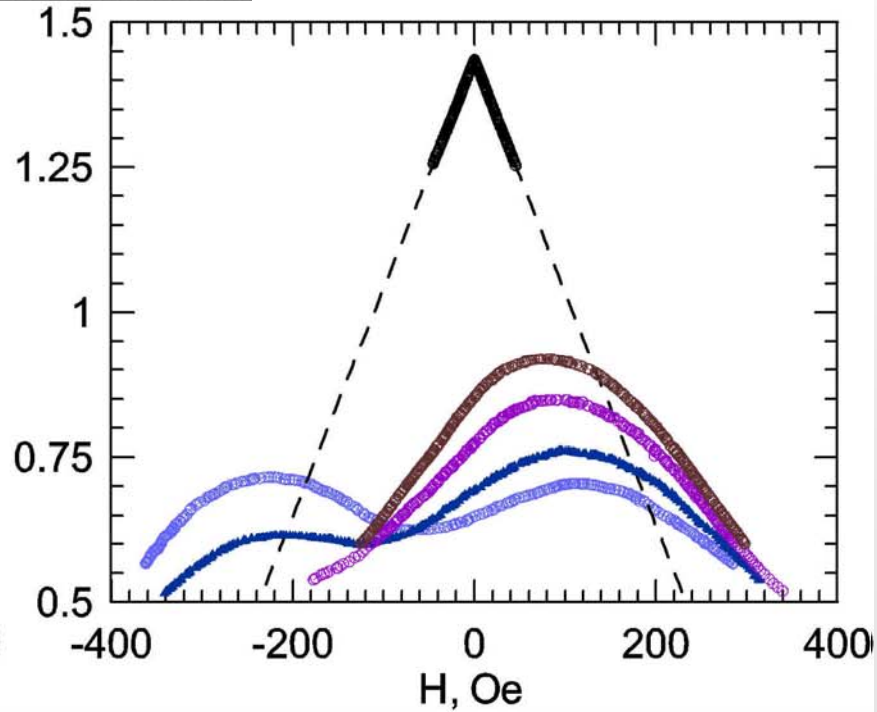
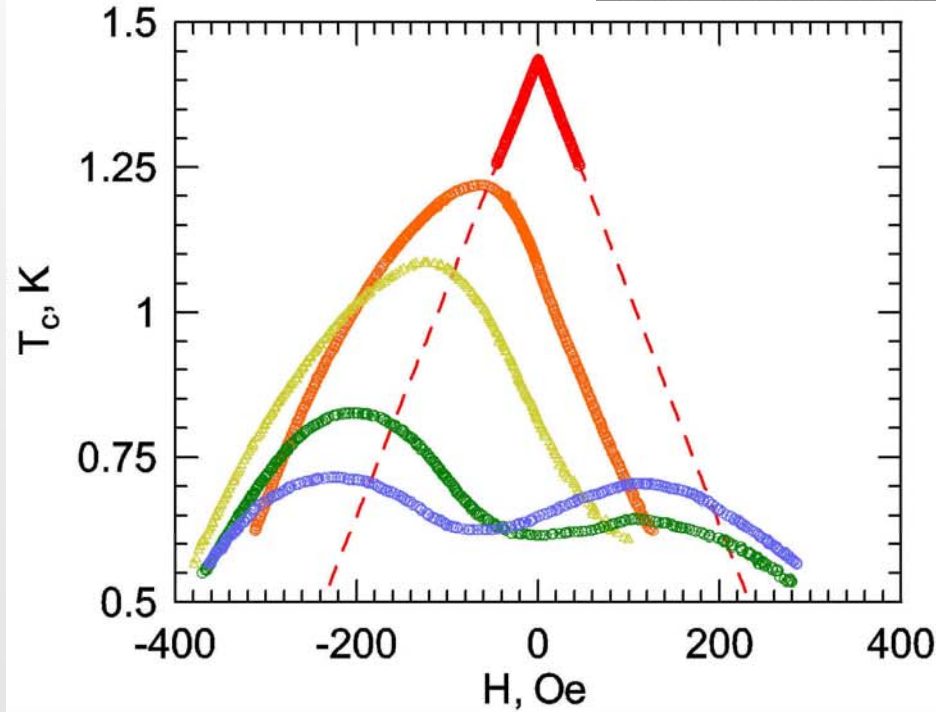
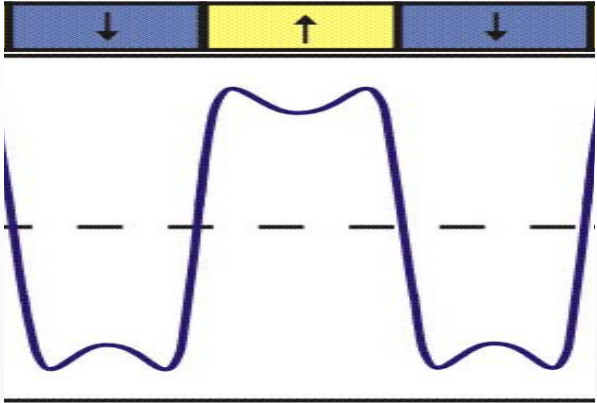
$$-\left(\nabla + \frac{2\pi i}{\Phi_0} \mathbf{A}\right)^2 \Psi = \frac{1}{\xi^2(T)} \Psi$$

Quantum-size effect:

$$E \propto \frac{1}{\ell^2} \Rightarrow \left(1 - \frac{T_c}{T_{c0}}\right) \propto \frac{\xi_0^2}{\ell^2}$$



Quantum confinement effect



W. Gillijns et al., PRB 76, 060503 (2007)

Conclusions

- The presence of domain-wall superconductivity is shown in planar S/F-multilayers
- The superconducting order parameter can be localized at will in certain positions of the sample
- Tunability is achieved by controlling the domain distribution in the ferromagnetic layer

Thanks for the attention