Summary of recent things

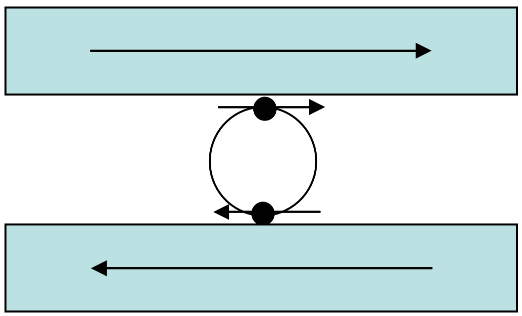
chris

13/09/06

Outline

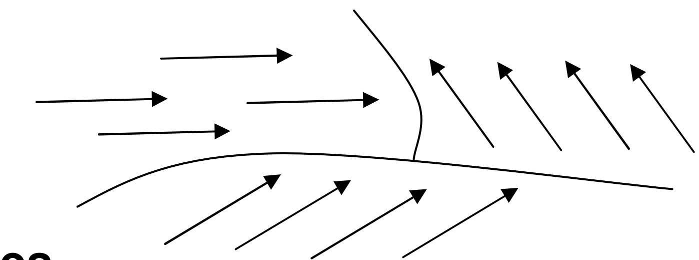
- Recent work on CuNi/Nb
  - bilayer
  - trilayers
  - future
- FeMn
  - conflict with the USA
  - ideas for FeMn
  - experiments to date

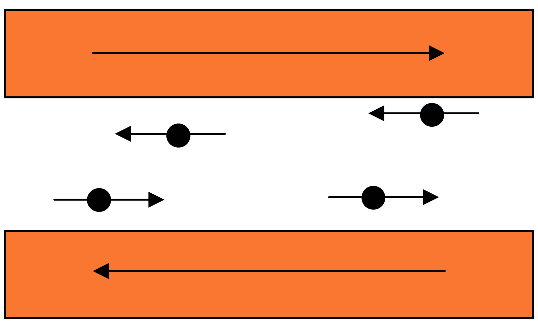
Reminder



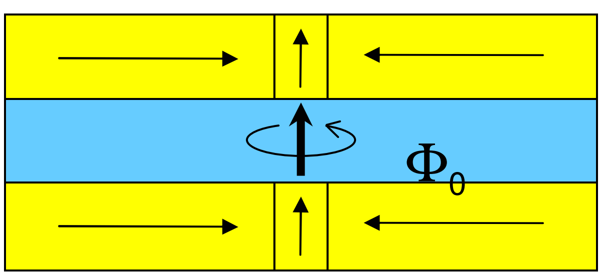
Cooper pairs

Averaging over H_{ex} for several domains / walls



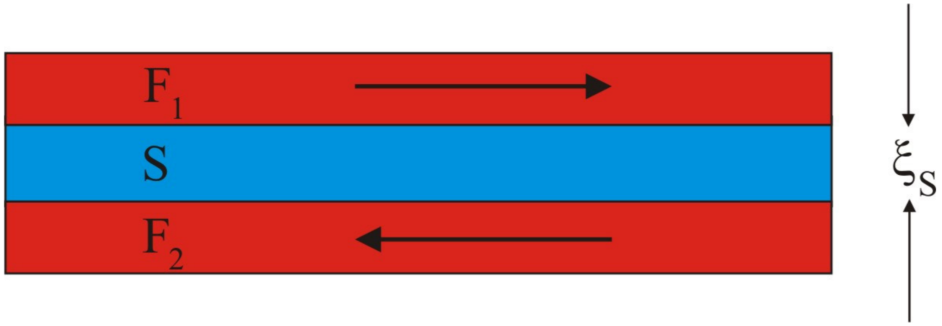


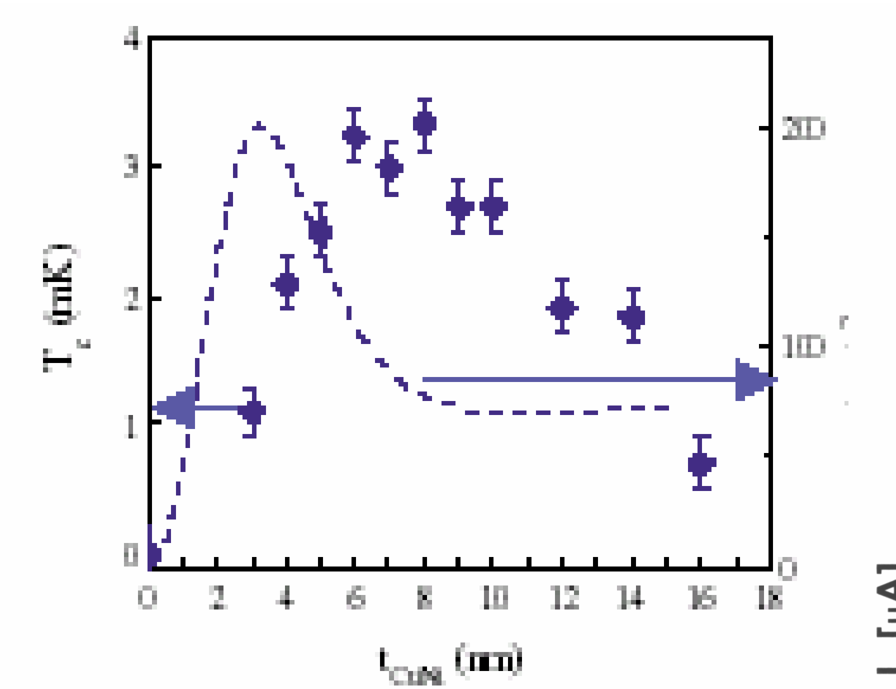
Trapped quasiparticles



Vortices from domain wall

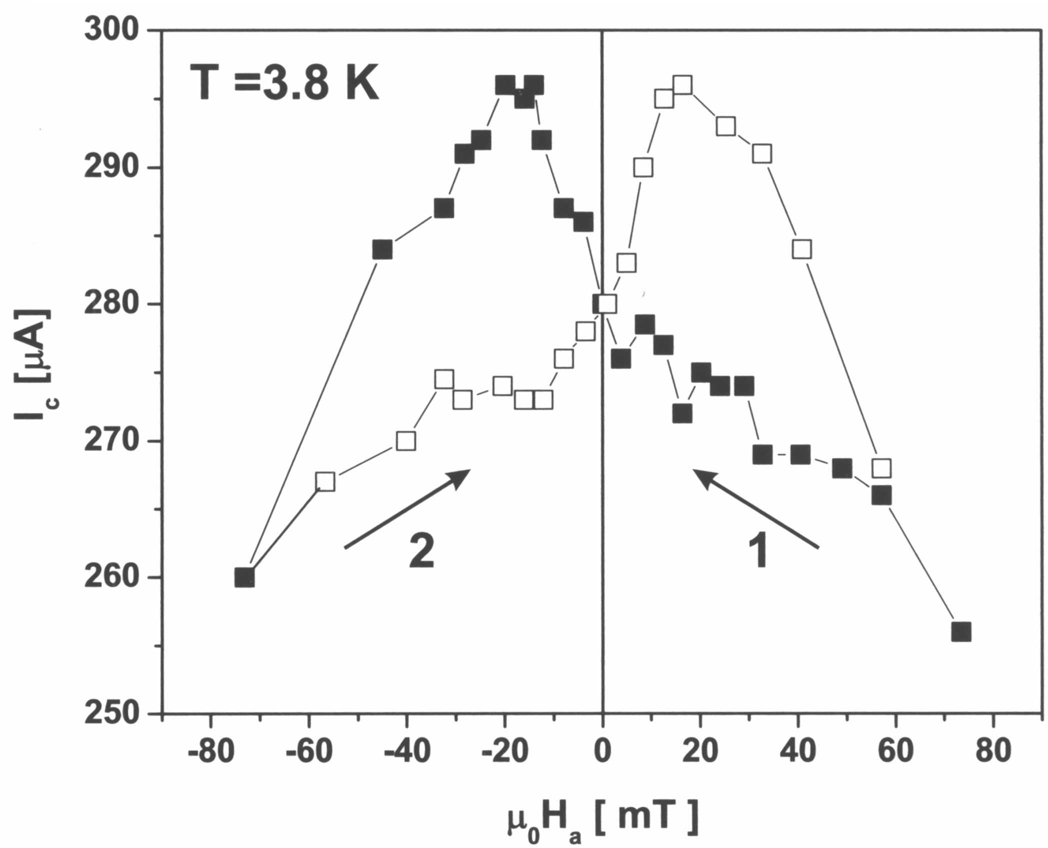
Previously





Gu et al Phys. Rev. Lett. **89** (2002) F = CuNi

Rusanov thesis



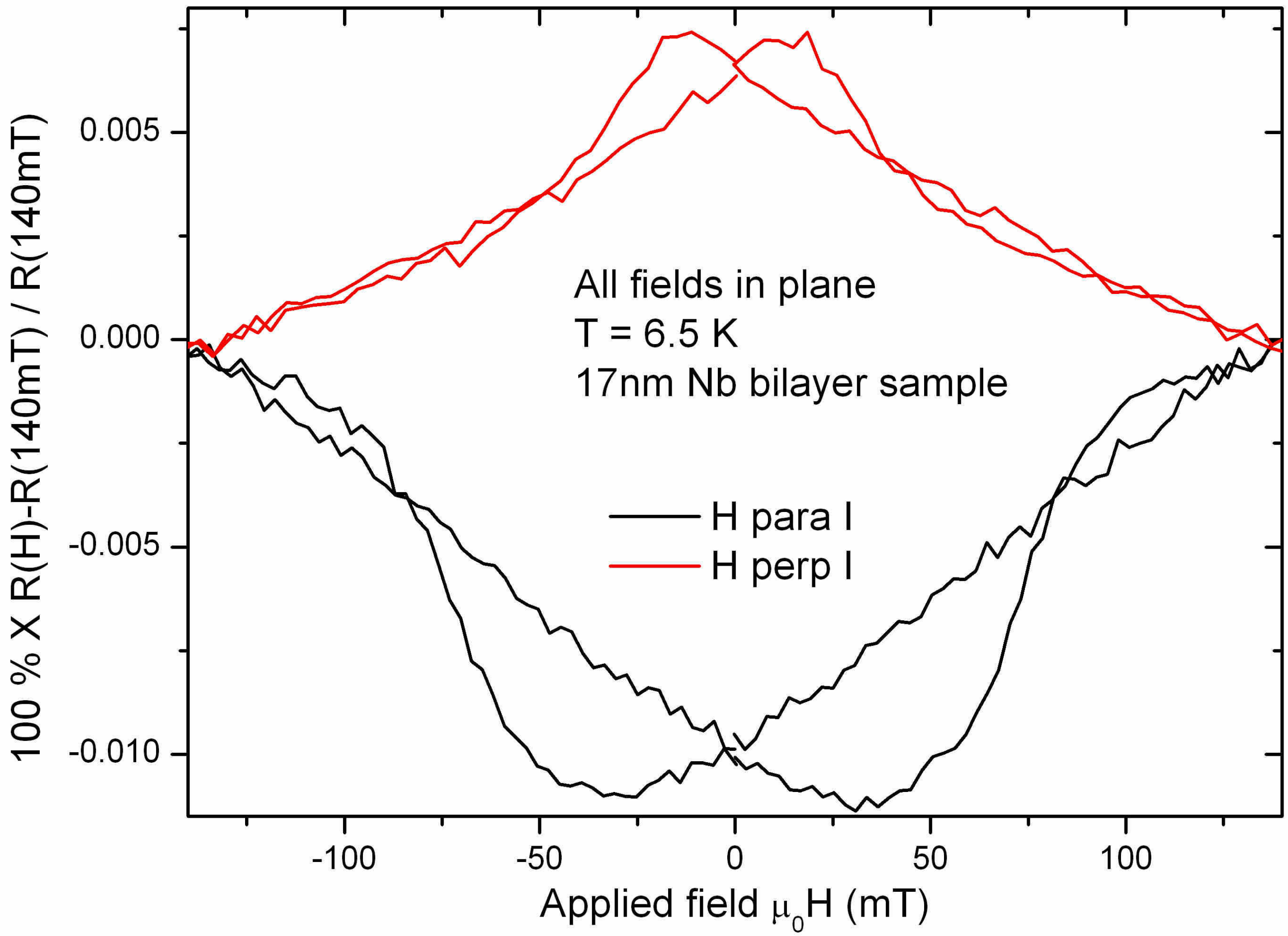
More recently

- GdNi/MoGe/GdNi: flux flow dominates in the domain state. Trilayers seem to show stronger effect than bilayers: due to extra suppression of Δ at 2 interfaces / coupling?!
- Py/Nb/Py: quasiparticles (see later)

Now

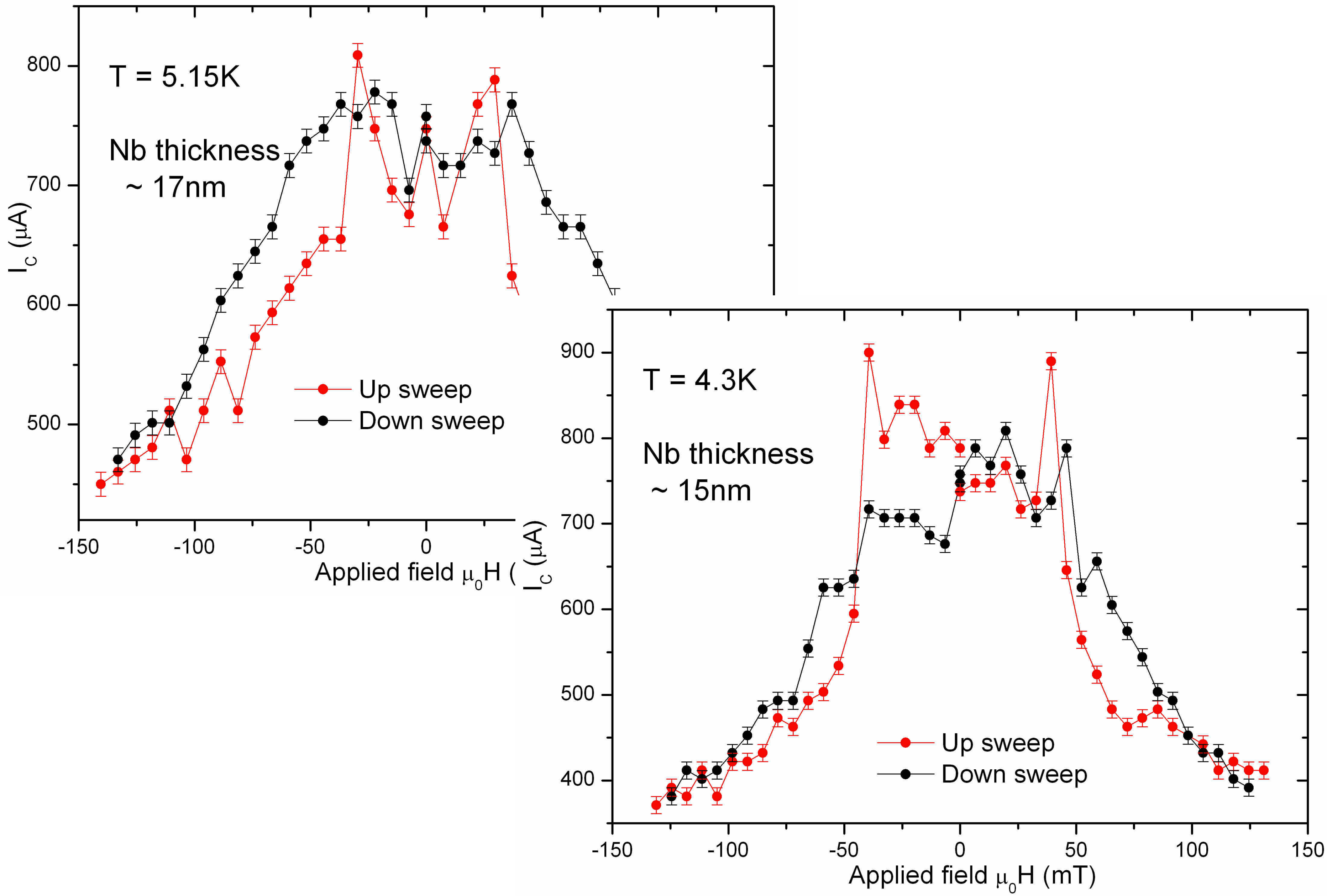
- What about CuNi/Nb/CuNi – is it Gu-esq enhancement, domains, flux?? what do bilayers do, and other thicknesses of CuNi?

CuNi/Nb bilayers

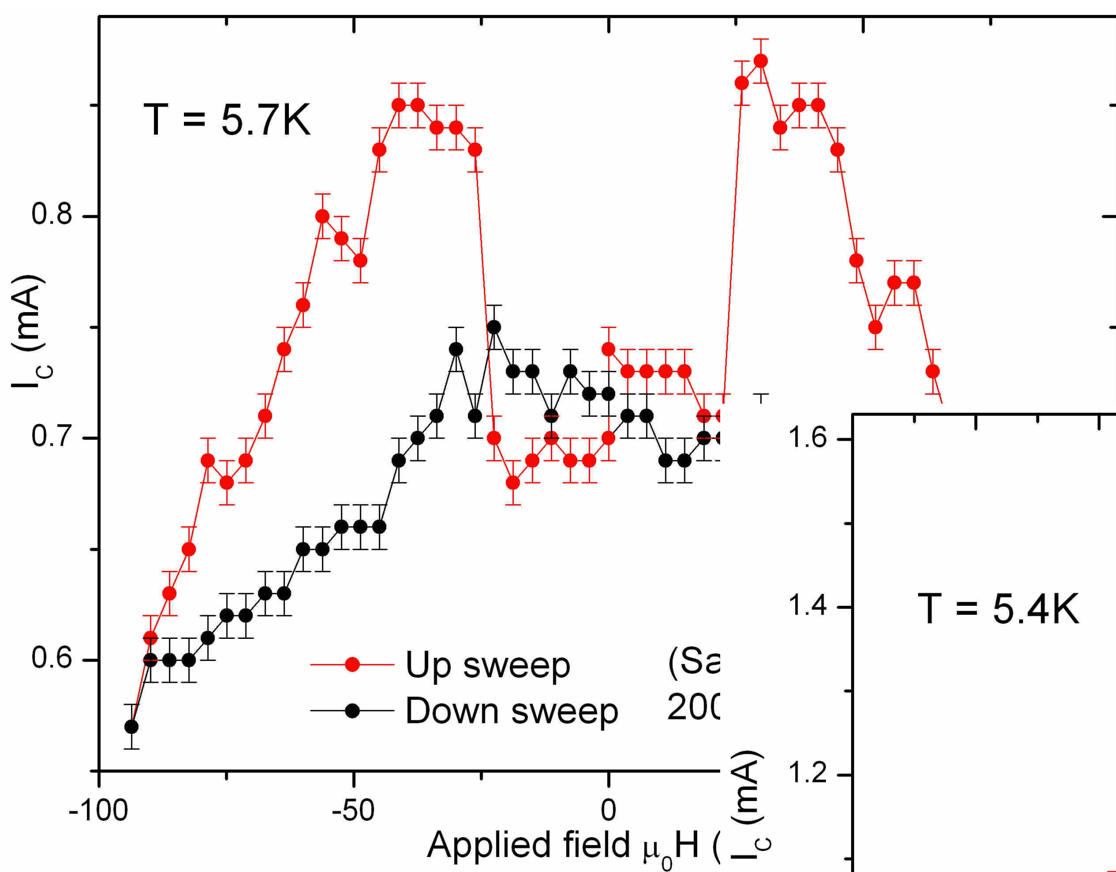


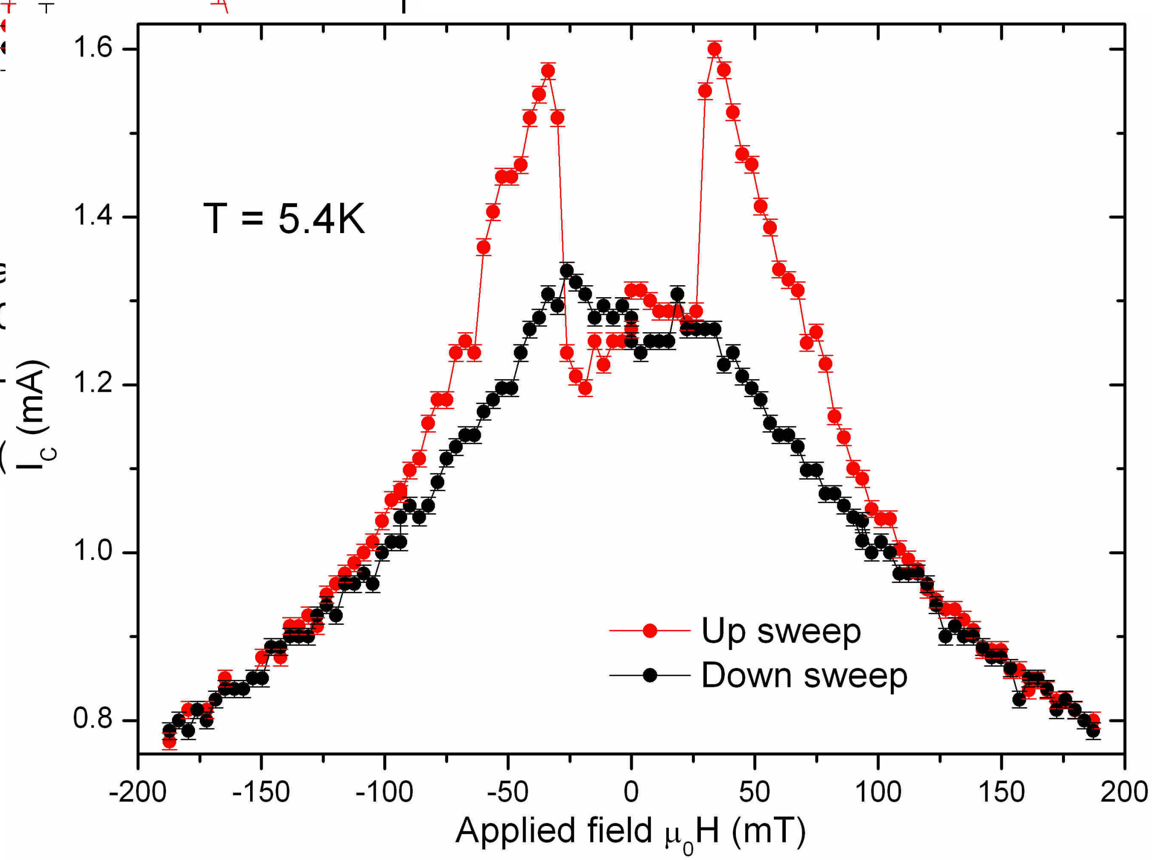
- Conventional AMR (c.f. PdNi is backwards!)

CuNi/Nb bilayers

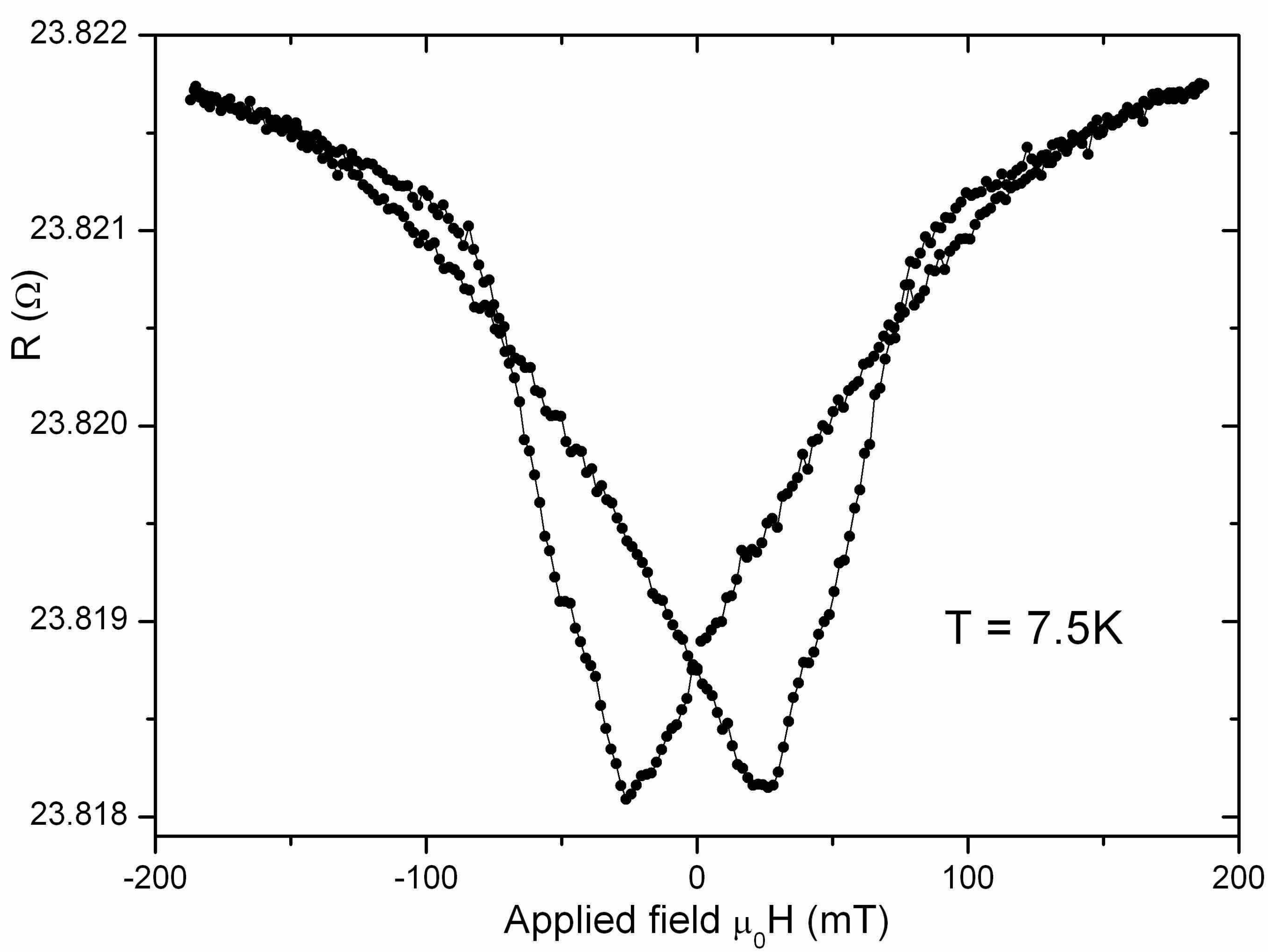


CuNi/Nb/CuNi trilayers (11nm CuNi)

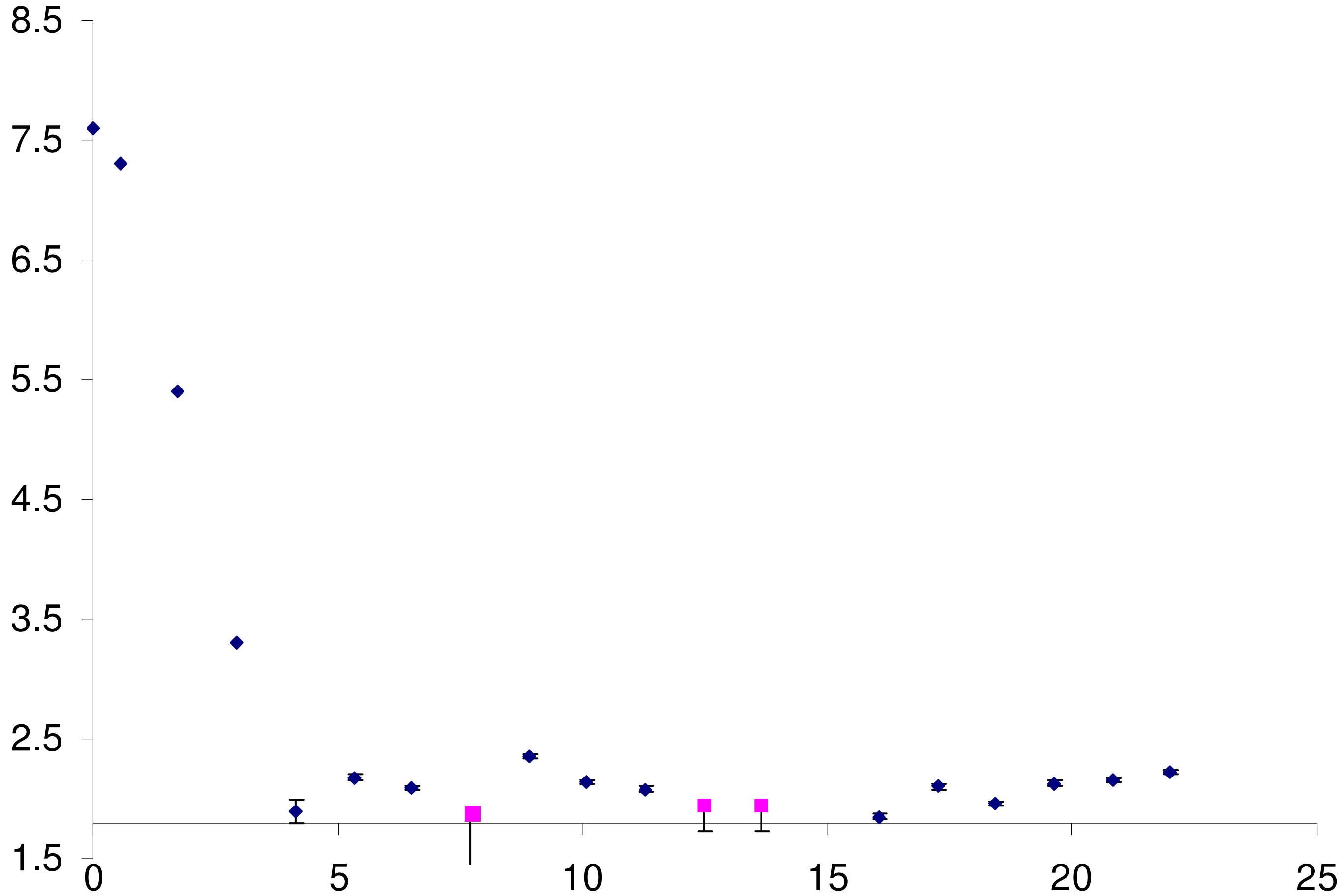




CuNi/Nb/CuNi trilayers

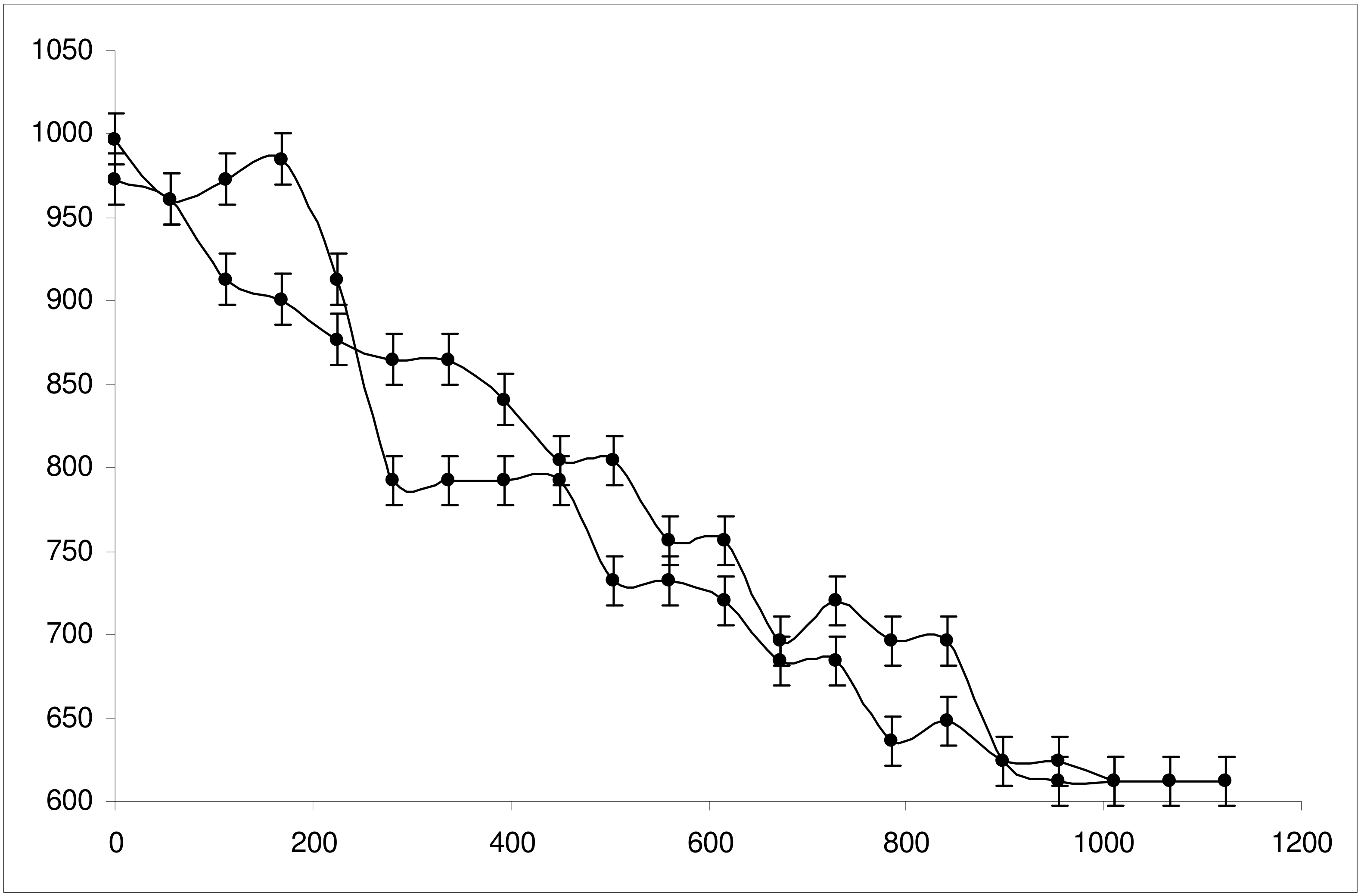


CuNi/Nb/CuNi now vary d_{CuNi}



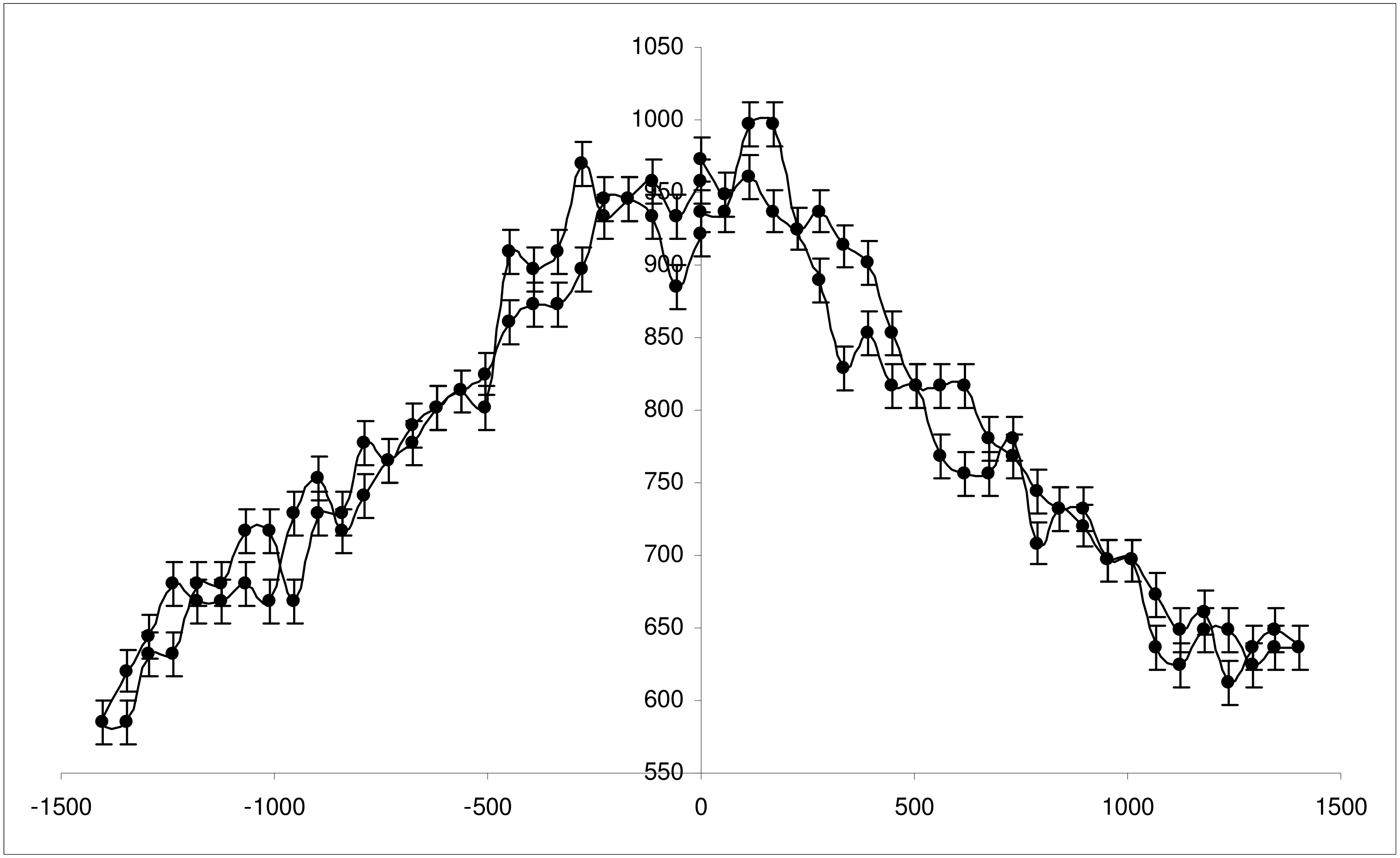
Thinner CuNi…. (constant Nb and T/T_c ~0.9)

- 8nm



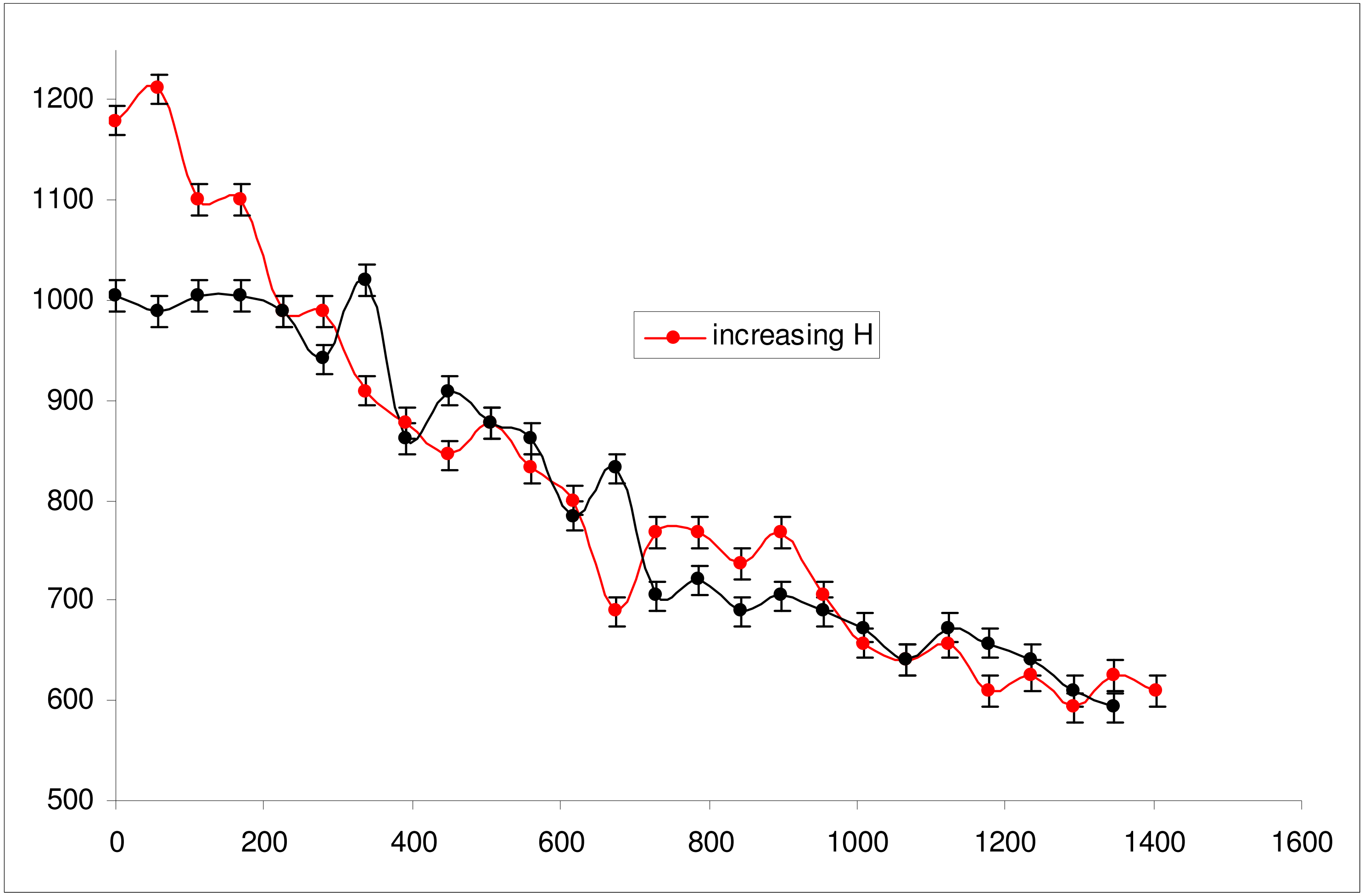
Thinner CuNi….

- 5nm



Thinner CuNi….

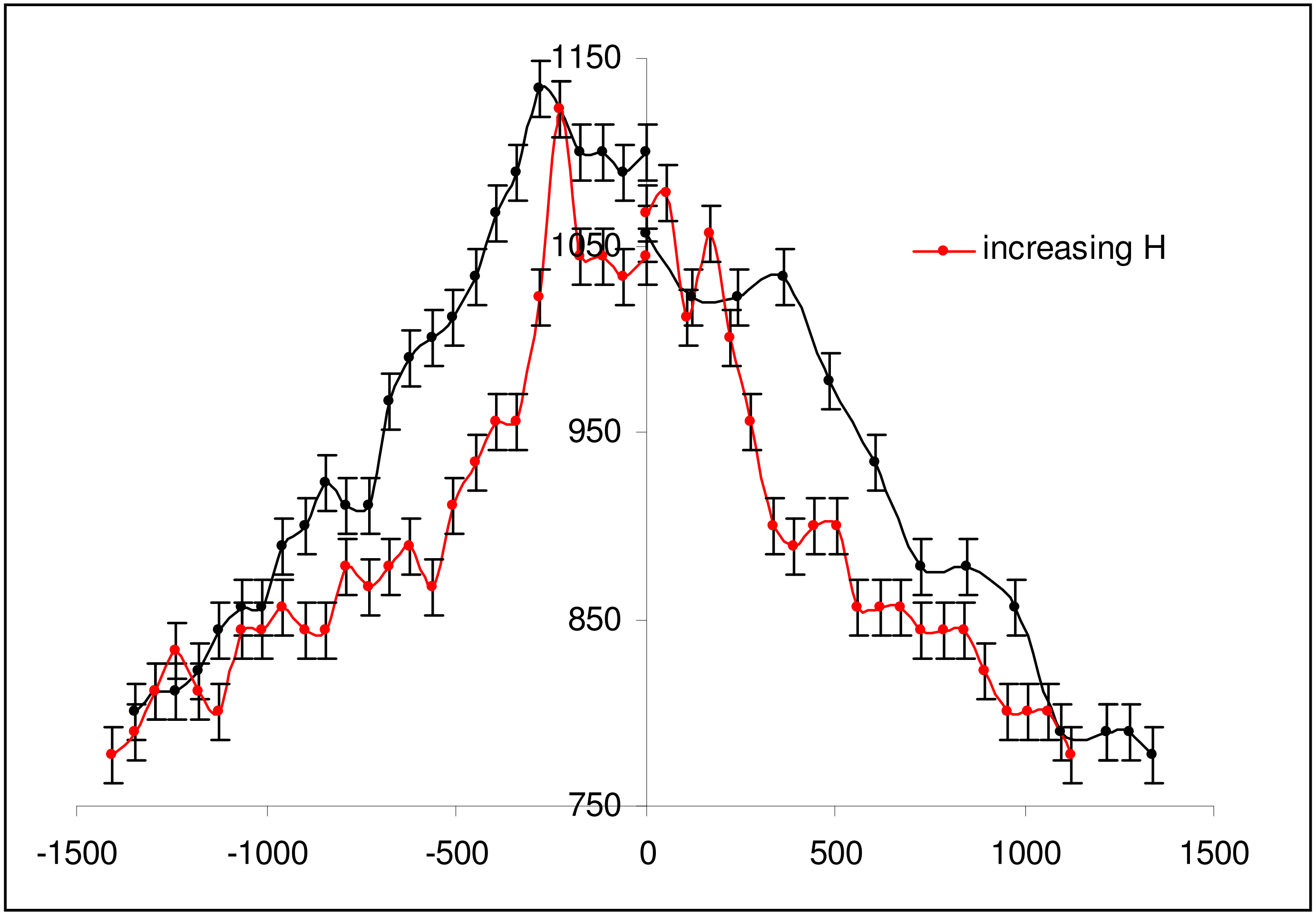
- 2.5nm



For thinnest layer AMR not above noise: don't know where the switching is happening

Not especially inspiring. so try: Thicker CuNi….

- Data from yesterday evening: ~ 14nm CuNi



Conclusions / Future

- Why does only one sample show this nice data?
- Measure final thicker CuNi sample
- Are there processing / measurement questions (some double steps in the R(T) curves aren't encouraging)
- Look carefully at any variation in sample geometry (ebeam maybe not so reproducible at 4mm field and <2μm features)

Py and FeMn

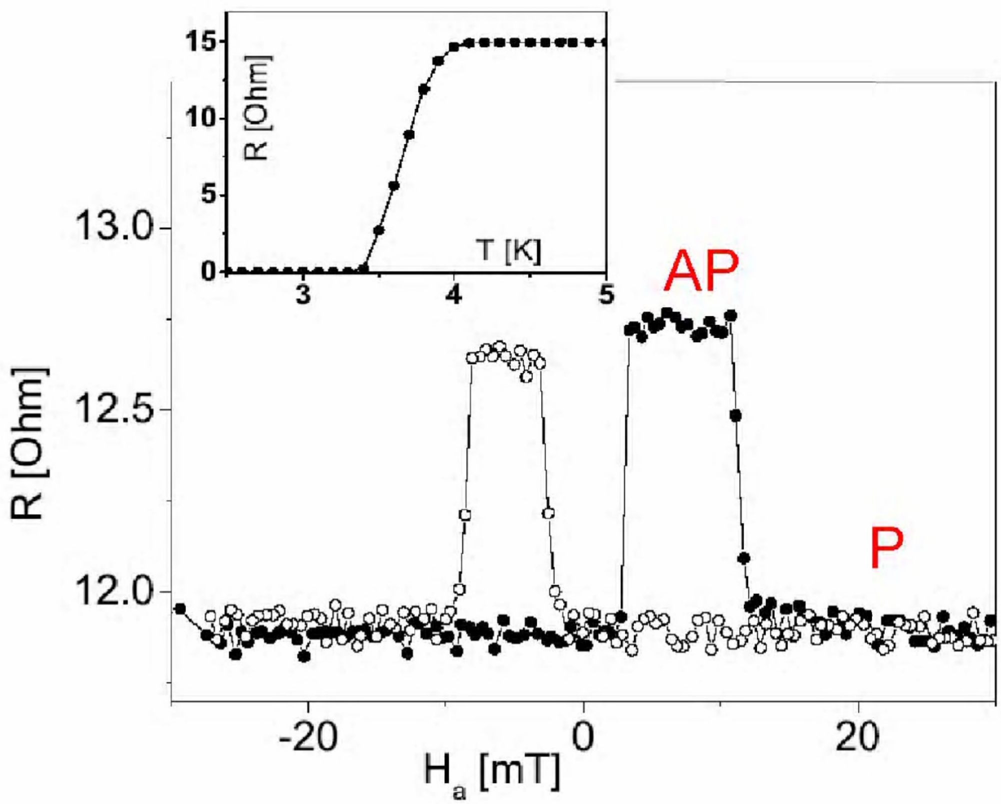
via Google, a talk from Birge:

Just when you thought everything was under control …

Rusanov, Habraken, & Aarts, cond-mat/0509156

Py/Nb/Py trilayer

$T_c^P > T_c^{AP}$!!

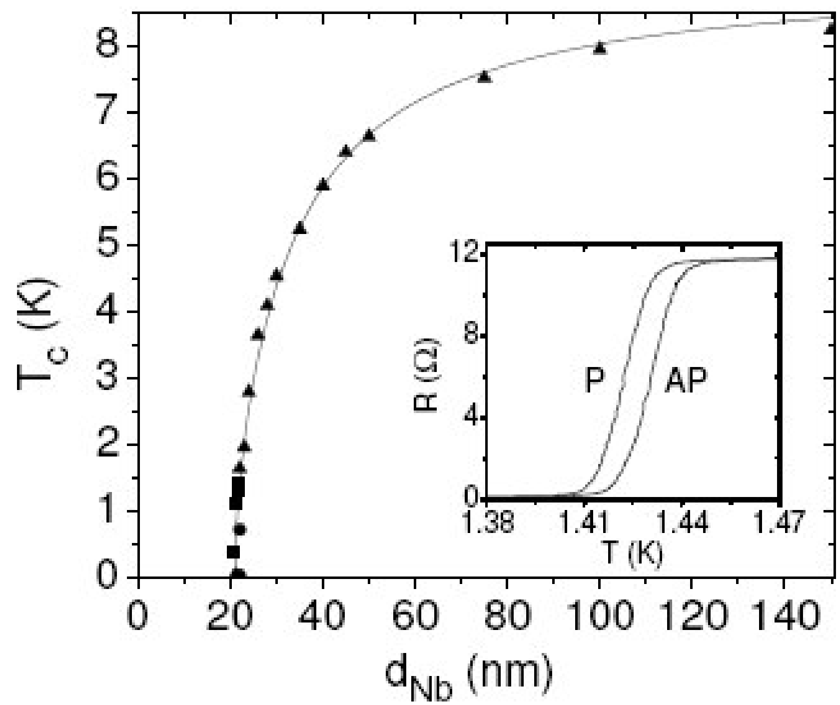


F/S/F in Py….

- **cond-mat/0608545**:

  Observation of standard spin-switch effects in F/S/F trilayers with a strong ferromagnet
  Ion C. Moraru, W. P. Pratt, Jr., Norman O. Birge
- Py(8)Nb(28)Py(8)**FeMn**(8)Nb

Follows on from their own work on CuNi, Ni and others on Fe (Westerholt et al.)

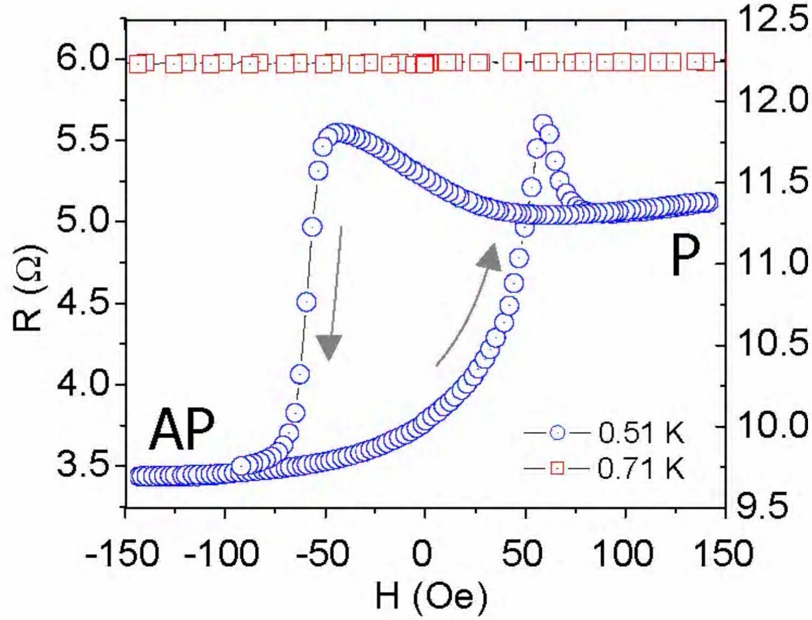


$Fe_{50}Mn_{50}$: relevance to F/S/F

“The question remains open as to why Rusanov et al.[14] observe inverse spin switch behavior, $T^P_c > T^{AP}_c$, whereas we observe the standard behavior, $T^P_c < T^{AP}_c$. The most obvious difference between our samples and theirs is that we use exchange bias to pin the magnetization direction of one Py layer, whereas they rely on the different coercivities of the two layers. But the switching data in their micron-scale samples show a clear plateau, which suggests that they have achieved a good AP magnetization configuration. A second comment is that they observe a difference between T^P_c and T^{AP}_c even when the Nb layer is very thick, 60 nm, whereas sensitivity to the ferromagnet orientation is limited to our samples with ds < 28 nm. Variations in resistance or T_c have also been observed in F/S bilayers due to domain formation during magnetization switching.[27,28] But Rusanov et al. state that the features indicating the inverse spin switch effect in their trilayers were not observed in bilayers. This fact, combined with their data in micron-scale samples that appear to be single-domain, argue against any role of domains in producing the inverse effect.”

from the same Google…

R vs. H

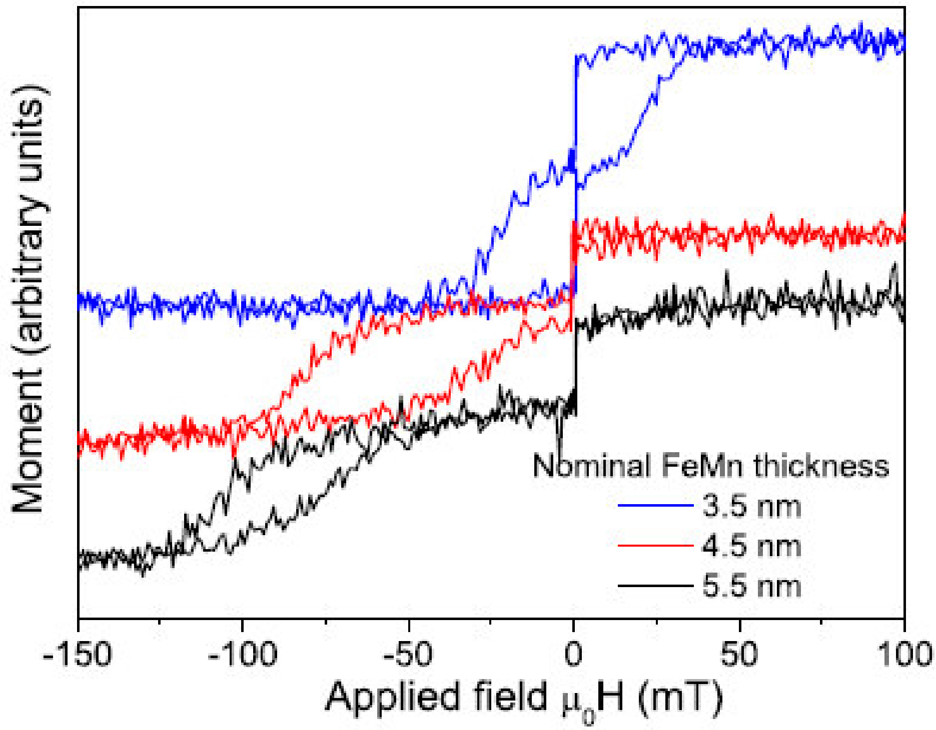


This is only for Ni/Nb/Ni: what does their Py data look like?

- Anti-Parallel Domains Parallel

- H ~ -100 Oe H ~ ± 10-50 Oe H ~ +100 Oe

f.c.c. γ-$Fe_{50}Mn_{50}$: exchange bias[1]



Spin diffusion length ~ 1.5 nm
(PRB 62 1178 (2000) Pratt's group (!))

1. C. Tsang, N. Heiman, and K. Lee, J. Appl. Phys. **52**, 2471 (1981).

Unclear and complex structure

Parallel Multi-teraflops Studies of the Magnetic Structure of FeMn Alloys
Canning et al. IEEE Computer Society, International Parallel and Distributed Processing Symposium (IPDPS'03)

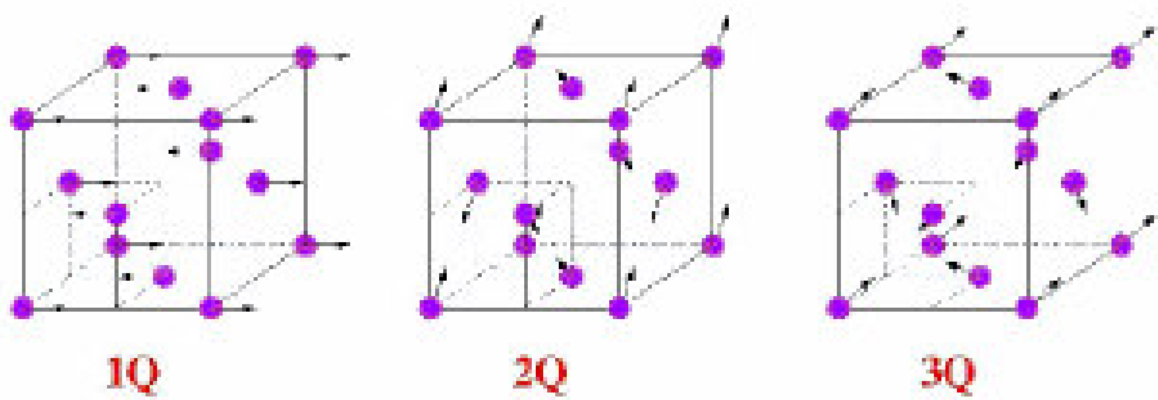


Figure 1. Candidate 1Q (left), 2Q (center), and 3Q (right) antiferromagnetic orderings of face centered cubic $Fe_{0.5}Mn_{0.5}$ solid solution alloys. The arrows show the directions of the local magnetic moments.

$Fe_{50}Mn_{50}$: proximity effect

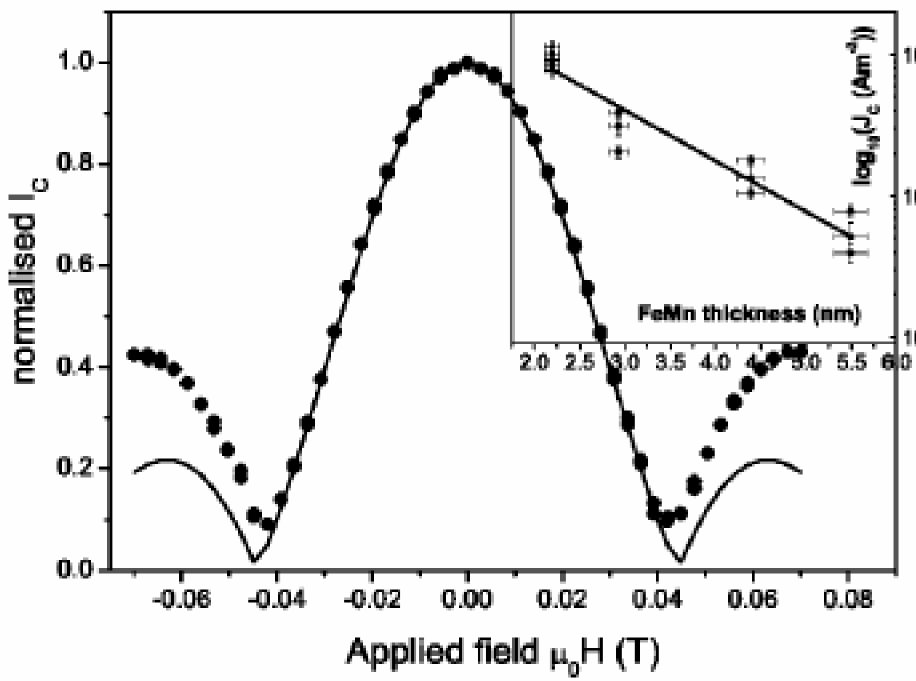


FIG. 4. Critical current modulation with an applied magnetic field, normalized to the zero field I_C. Line is a best-fit Fraunhofer pattern. Inset: Critical current density vs FeMn thickness for junctions at 4.2 K. Line is a best fit exponential $\exp(-2d_{AF}/\xi_{AF})$ with $\xi_{AF} = 2.4$ nm.

PHYSICAL REVIEW B **68**, 144517 (2003)

Just as bad as a ferromagnet to kill superconductivity

ξ_{FeMn} ~2.4 nm

$Fe_{50}Mn_{50}$: ideas / experiments to come

- Nb/Py vs Nb/Py/FeMn

Q: for thin enough Py does the FeMn change the proximity effect?

A: Probably yes – but what is thin? Birge et al. use **<u>8nm Py</u>** –already thick for Cooper pairs, but not so thick for spin polarised electrons: spin diffusion length[1] =

4.3 ±1 or 5.5 ±1 nm

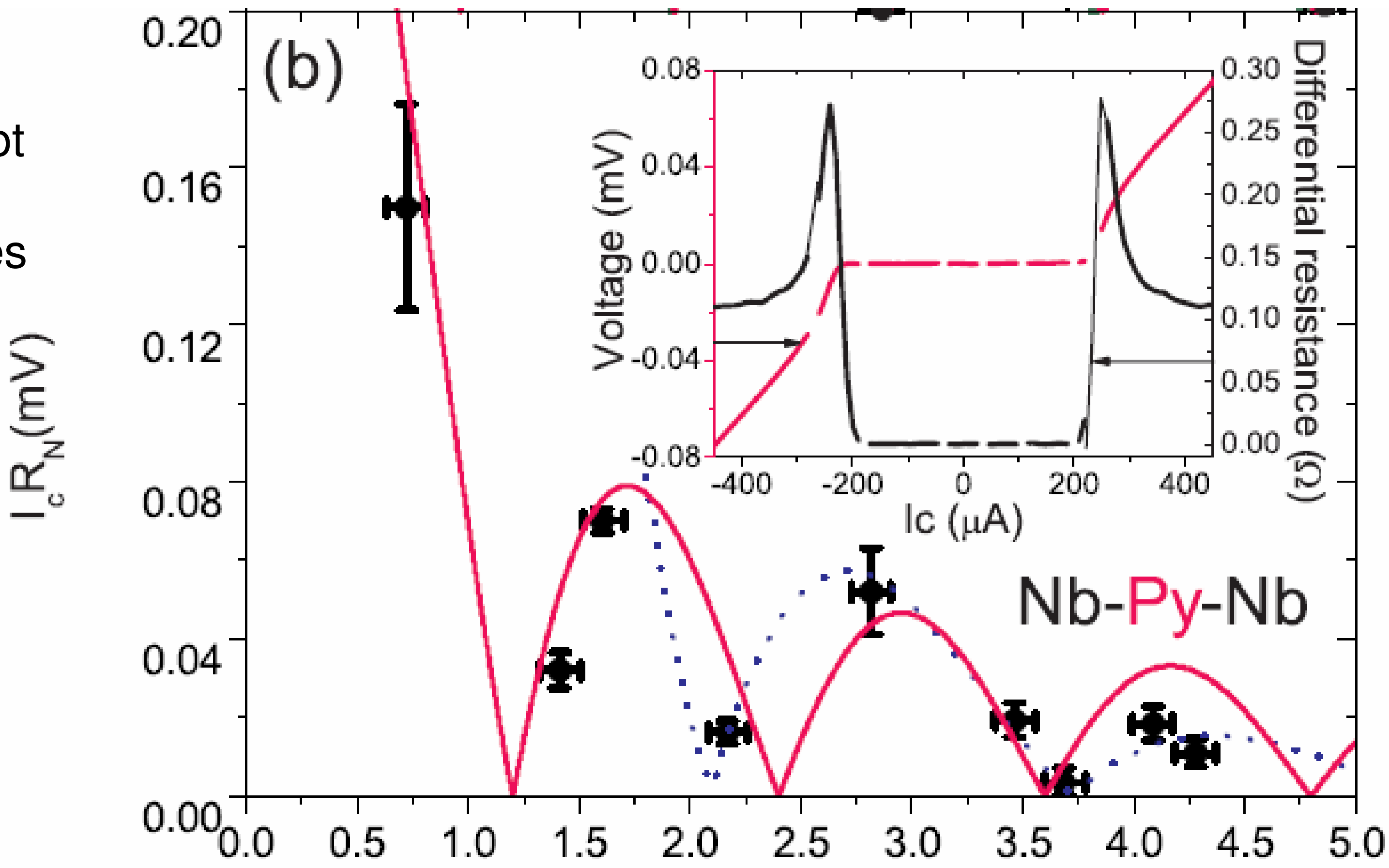
- So maybe Py/Nb/Py/FeMn will be more sensitive than single Py layers

1. Steenwyk et al. JMMM 170, L1 (1997); Pratt et al. IEEE Trans. Magn. 33, 3505 (1997); S. Dubois et al., Phys. Rev. B 60, 477 (1999)

Nb/Py/Nb[1]

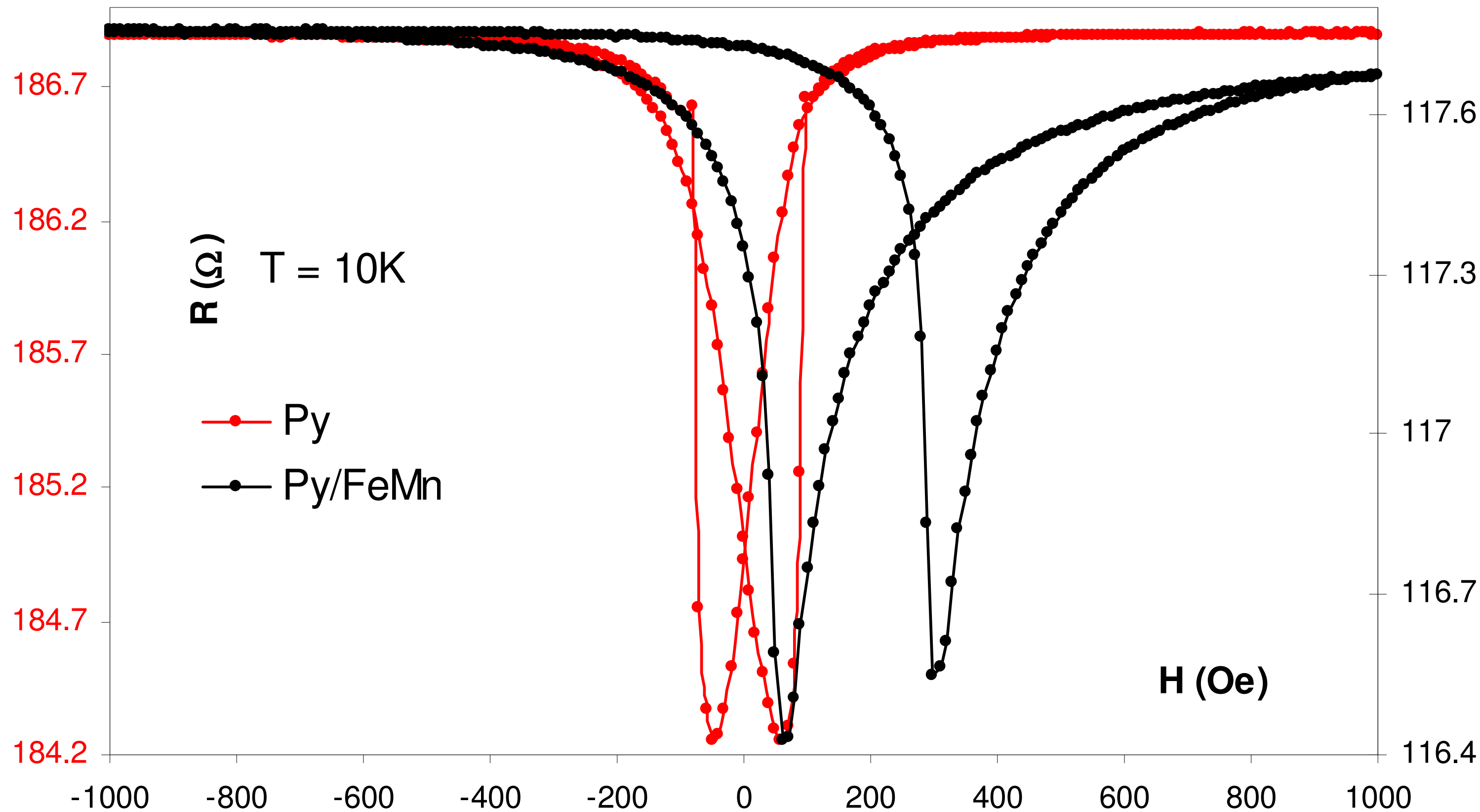
ξ_1 (nm)	ξ_2 (nm)
1.2	1.6

This is maybe not the definitive ξ_F, but the data gives you some idea also



1. Robinson et al. cond-mat/0606067

$Fe_{50}Mn_{50}$: experiment to date



FeMn ~30 nm Py ~ 15nm

AMR not so easy to extract H_{bias}, Py also a bit thick – but works!

(Also no controlled magnetic field in the ATC – easy axis of Py unknown)

…watch this space

- Series of ‘bilayers’ and ‘trilayers’ to come (full set of new targets in the UHV, last bit of baking this morning)
- Hopefully soon we can say why the USA is different from Leiden
- Presumably Birge is looking at this too (unless he thinks the onus is on us)?!