βNMR Search for Magnetic Phase Separation in GaAs:Mn

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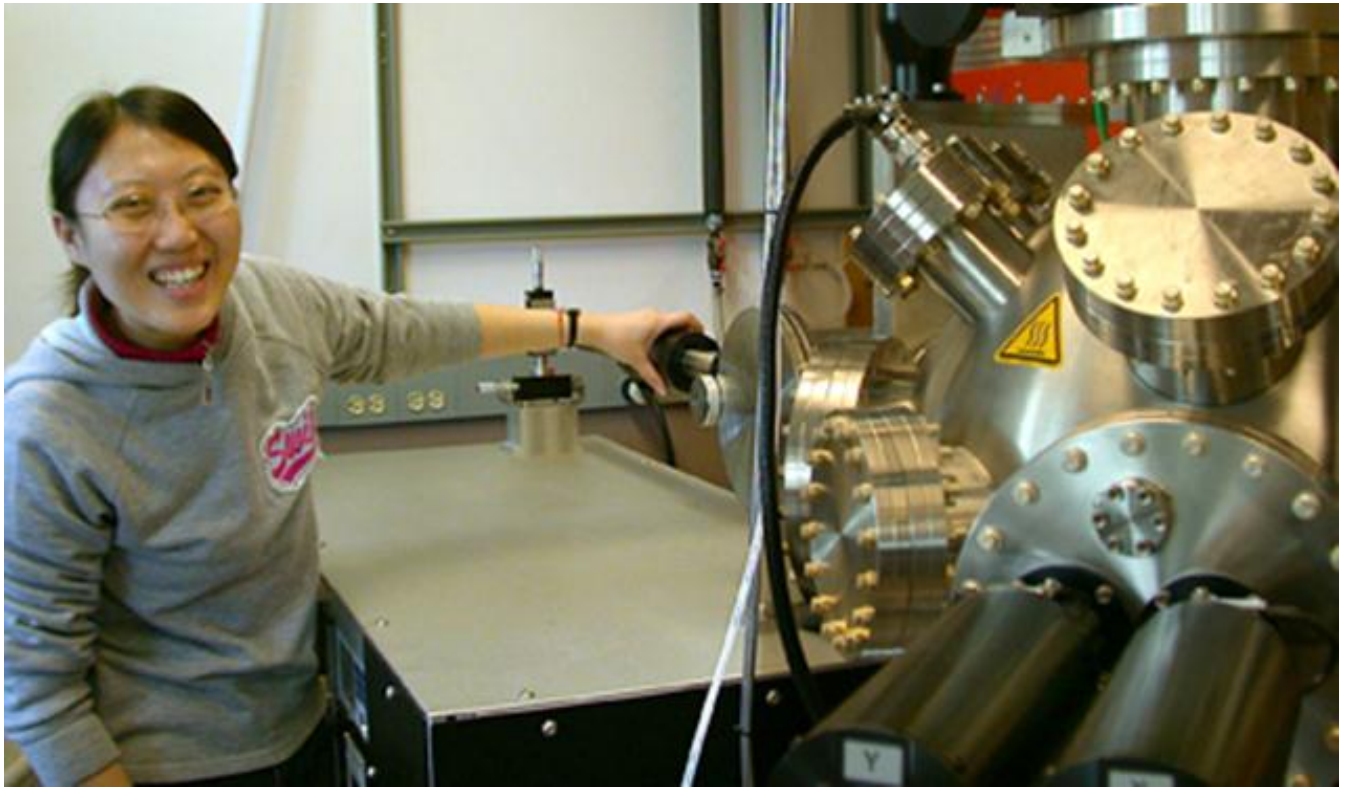
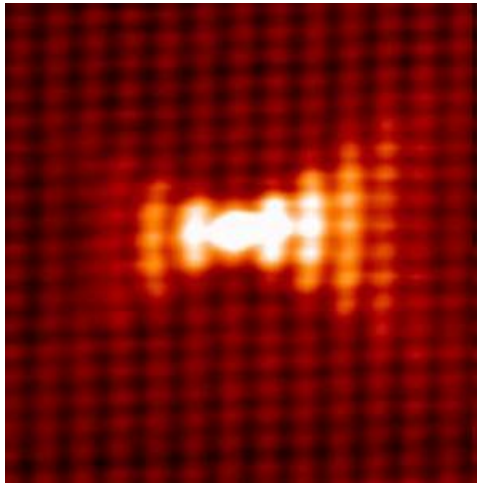


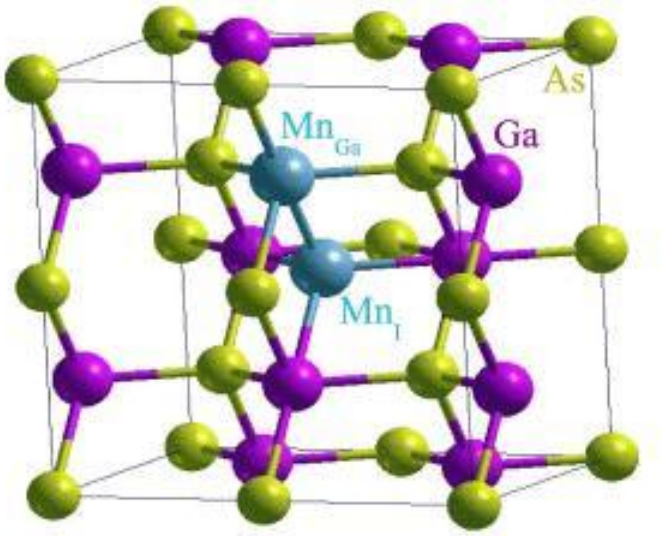
^{8}Li beta NMR differences

- Lifetime τ = 1.21 seconds (~1,000,000×μ^{+})
- S = 2, Q = +31.4 mb
- beta Energy ~ 6 MeV
- Low energy (< 30 keV) no “muon counter”
- ~2 weeks of beam per year ☹

Mn doped GaAs, a magnetic semiconductor



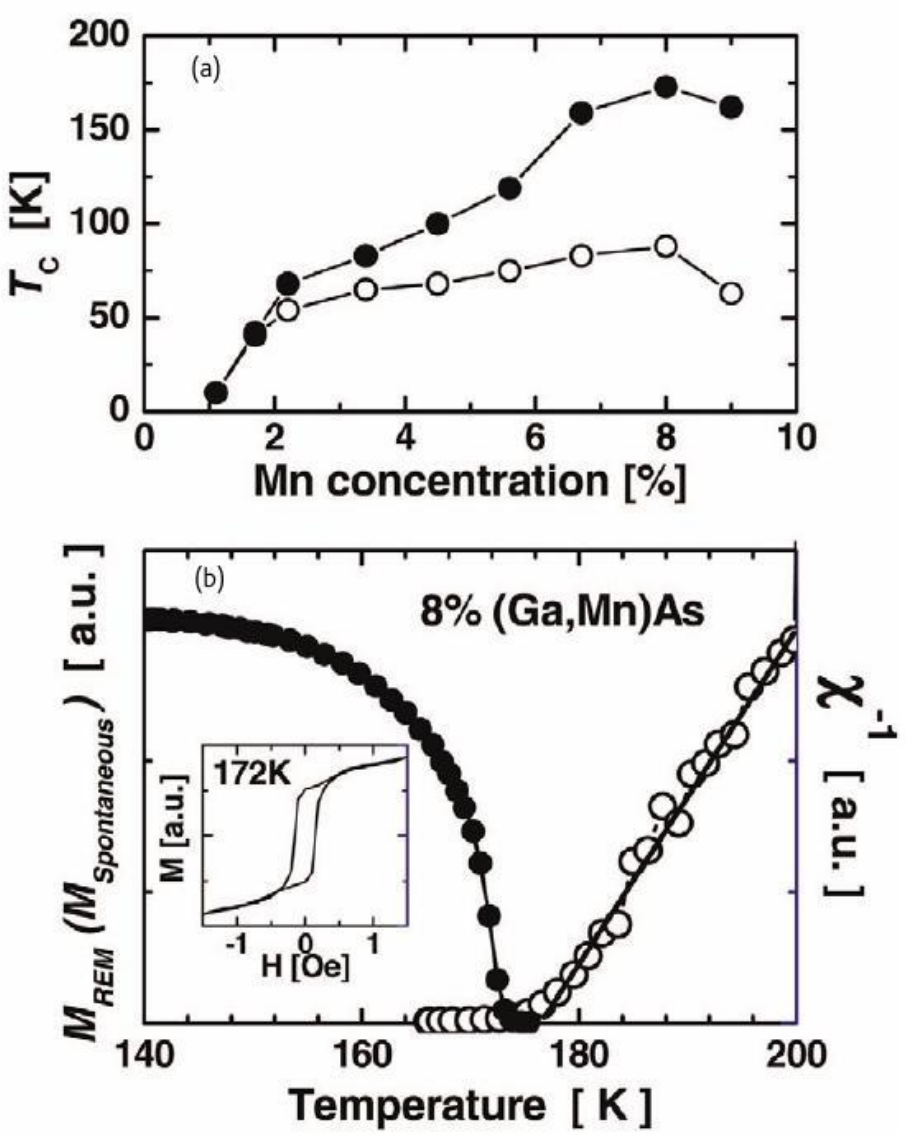
Mn acceptor (STM)
Yakunin et al. PRL **92**, 216806 (04)



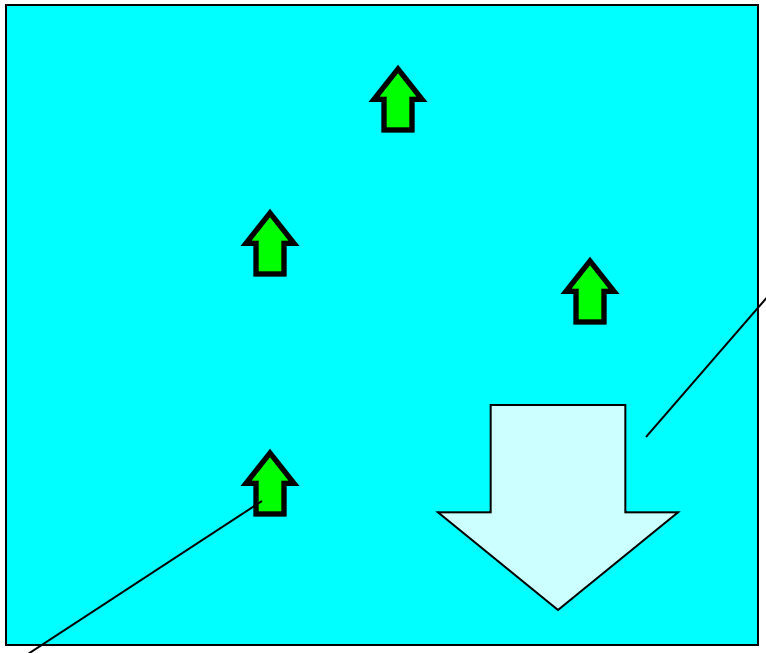
Substitutional (Ga): Acceptor
Interstitial: Double Donor

$Ga_{1-x}Mn_xAs$ is not stable in bulk

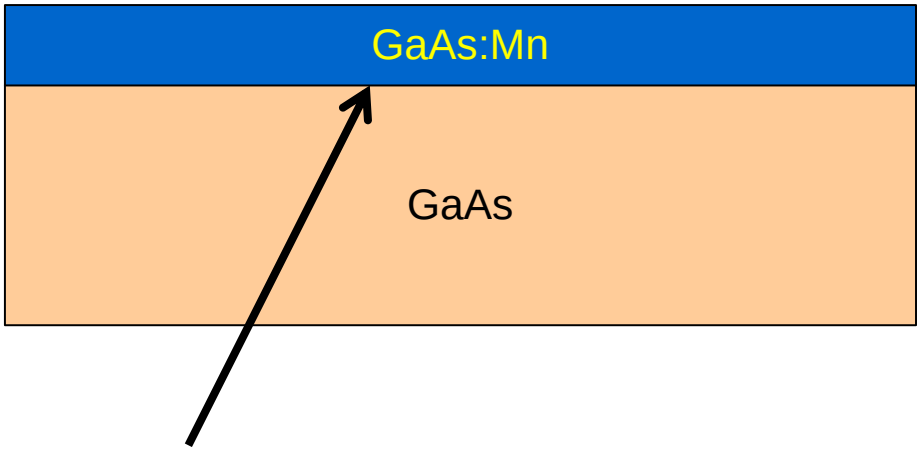
$Ga_{1-x}Mn_xAs$ a dilute magnetic semiconductor



Dilute Magnetic Semiconductors



Mn doped GaAs



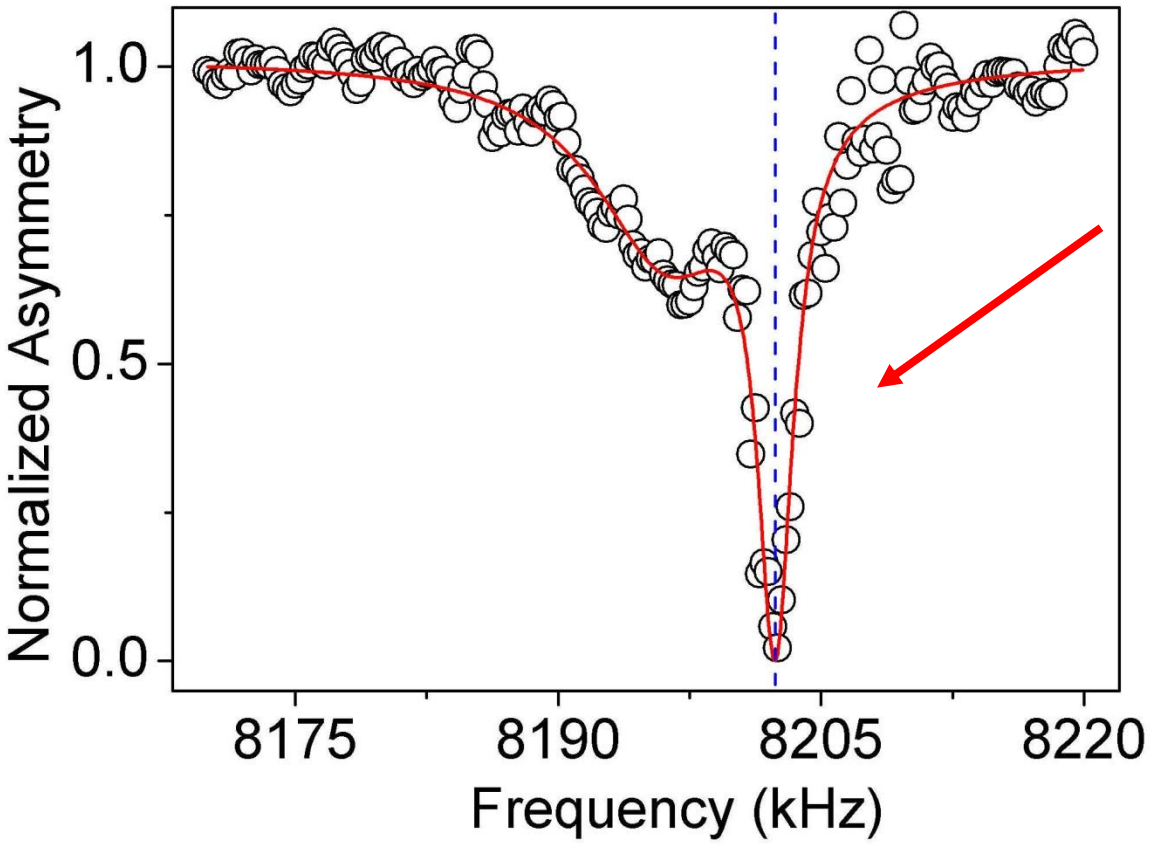
180 nm thick
5.4% Mn, Tc ~ 72 K

less impedance mismatch than with a metallic ferromagnet like Fe

An alloy, metallic

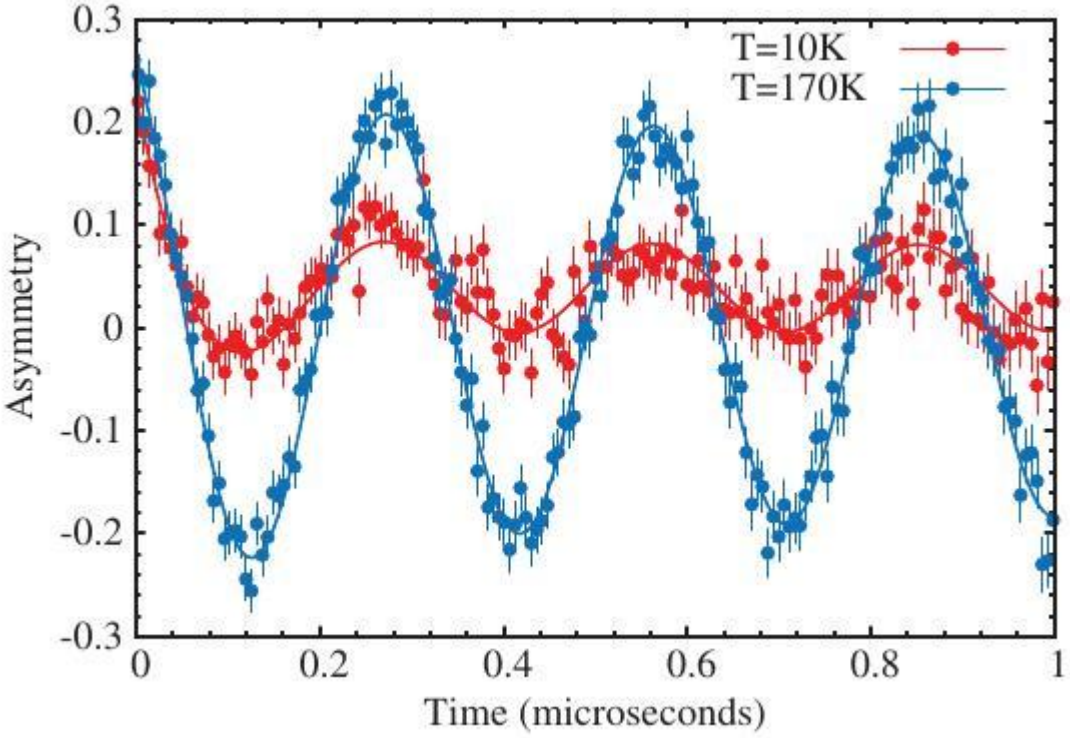
Sample: J.K. Furdyna, Notre Dame

^{8}Li resonance in 180 nm $Ga_{0.95}Mn_{0.05}As$ / GaAs



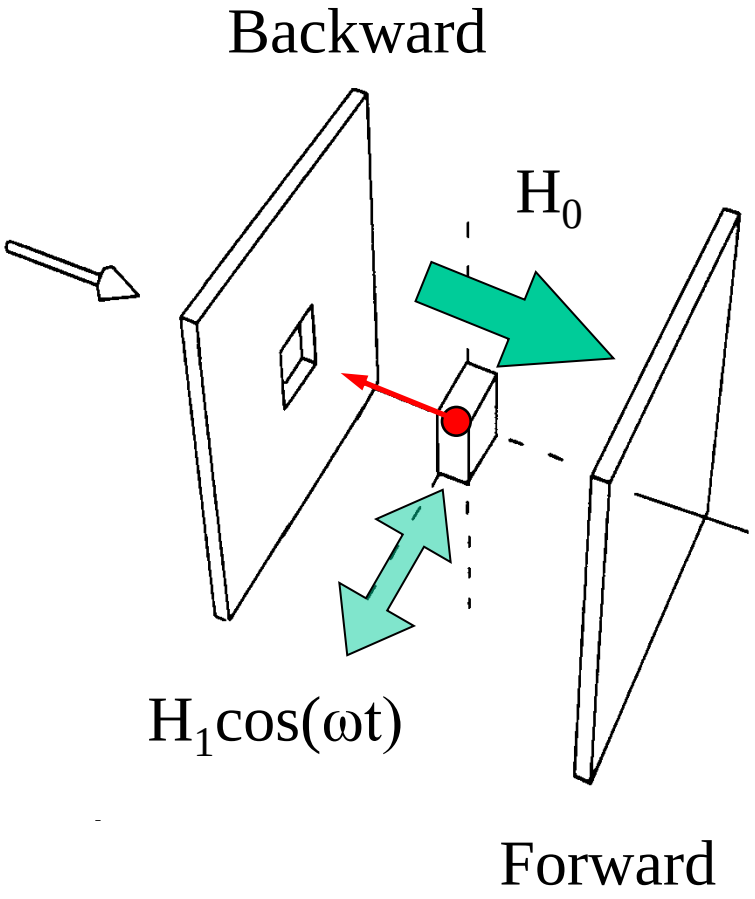
Sharp Substrate Line

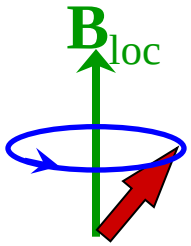
LEμSR evidence of phase separation



Storchak et al., PRL **101**, 027202 (08)

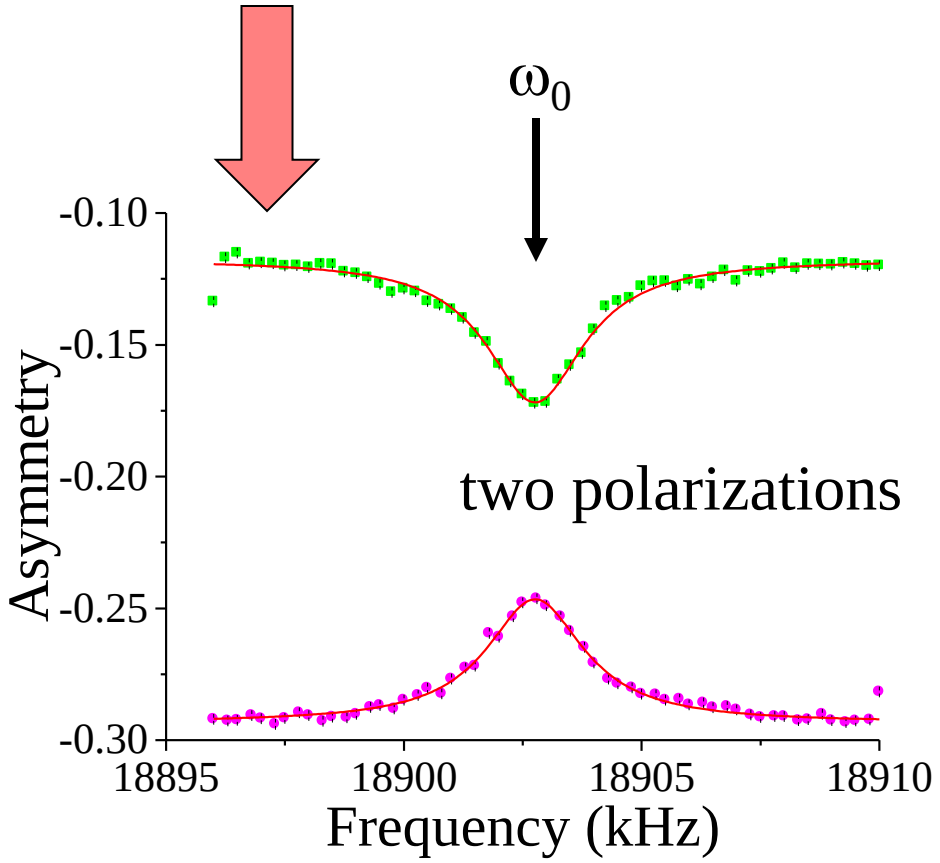
βNMResonance



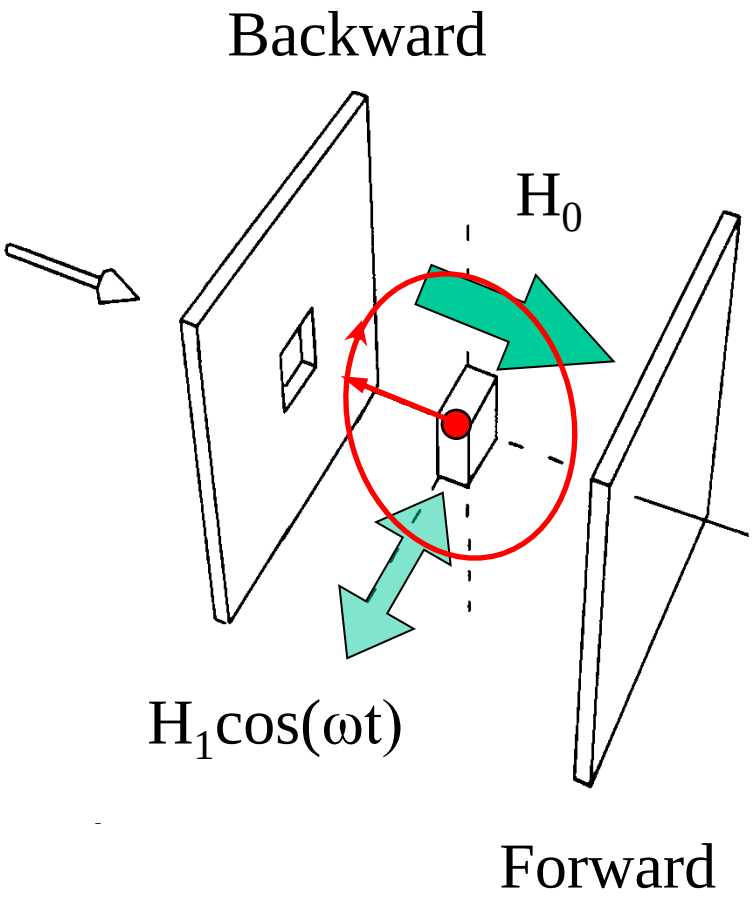


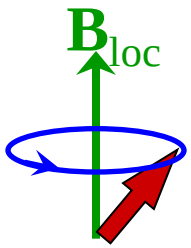
$$\omega_0 = \gamma H_0$$

off resonance $\omega < \omega_0$



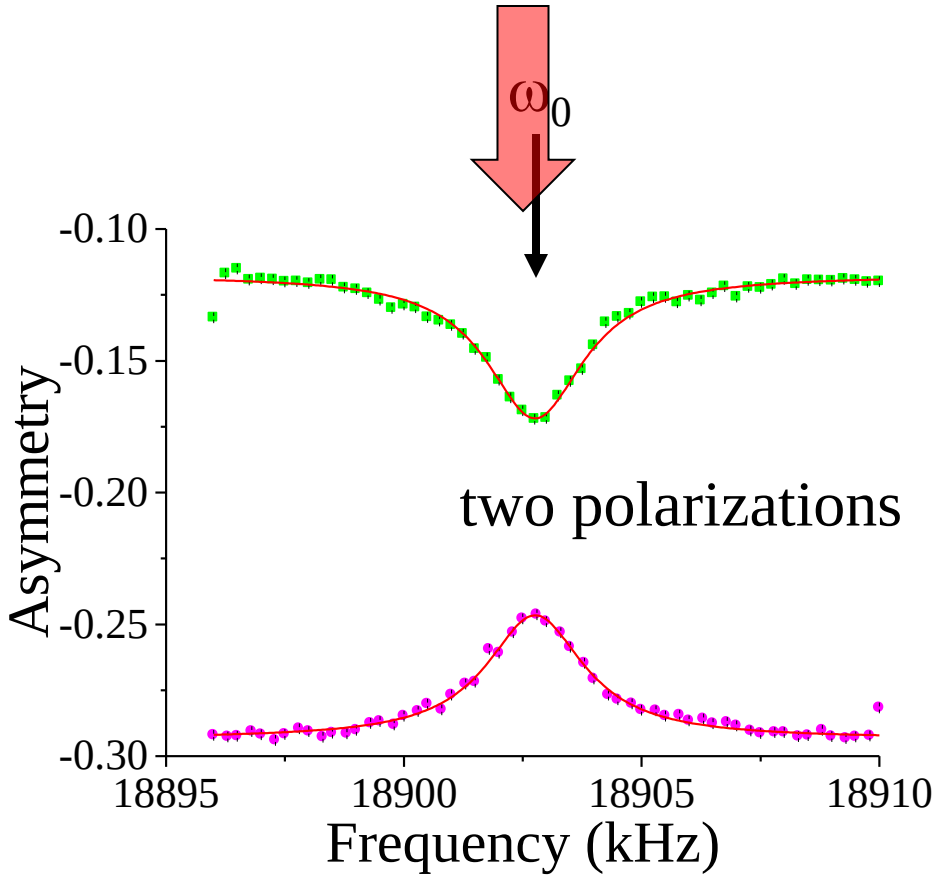
βNMResonance



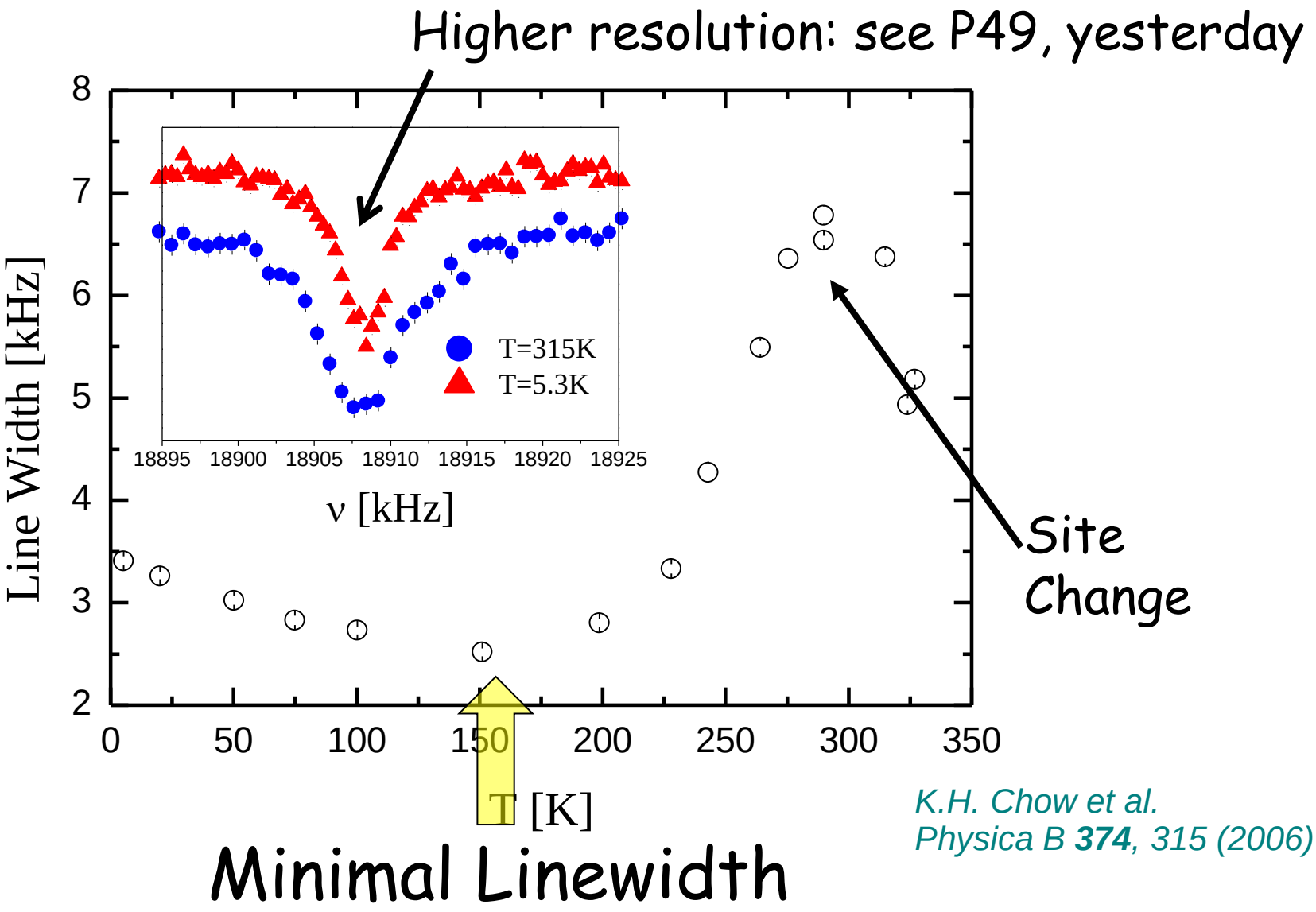


$$\omega_0 = \gamma H_0$$

on resonance $\omega \sim \omega_0$



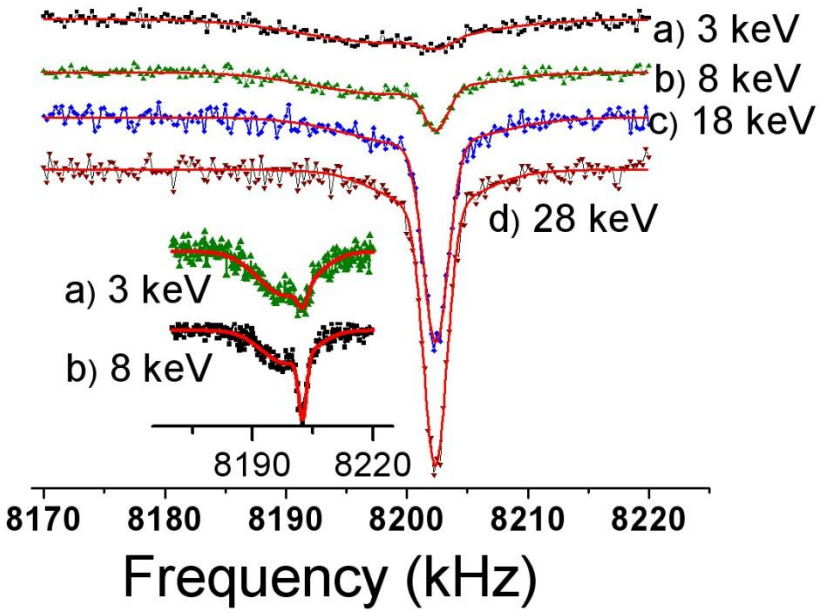
^{8}Li Resonances in Bare GaAs

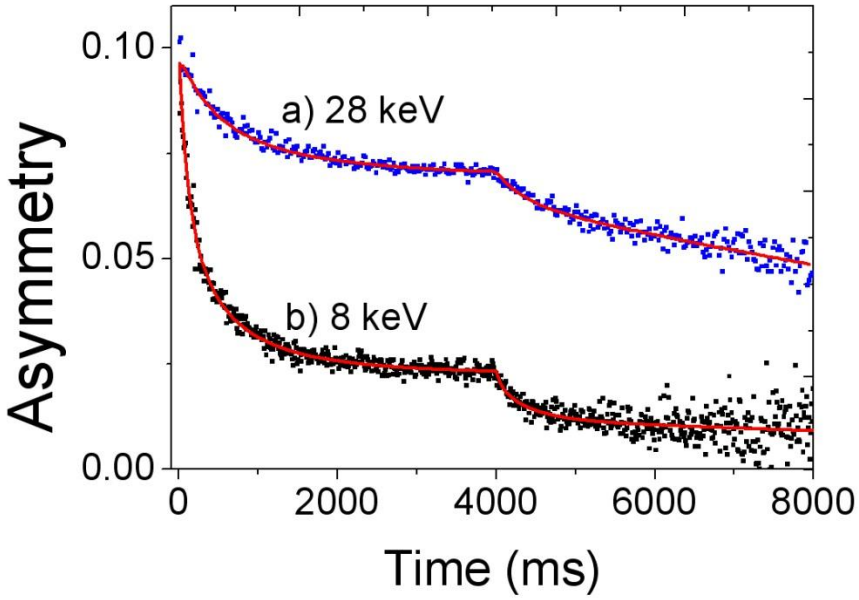


K.H. Chow et al.
*Physica B **374**, 315 (2006)*

Depth Dependence at 50 K (< T_C)

Q. Song et al., Physica B (2009)

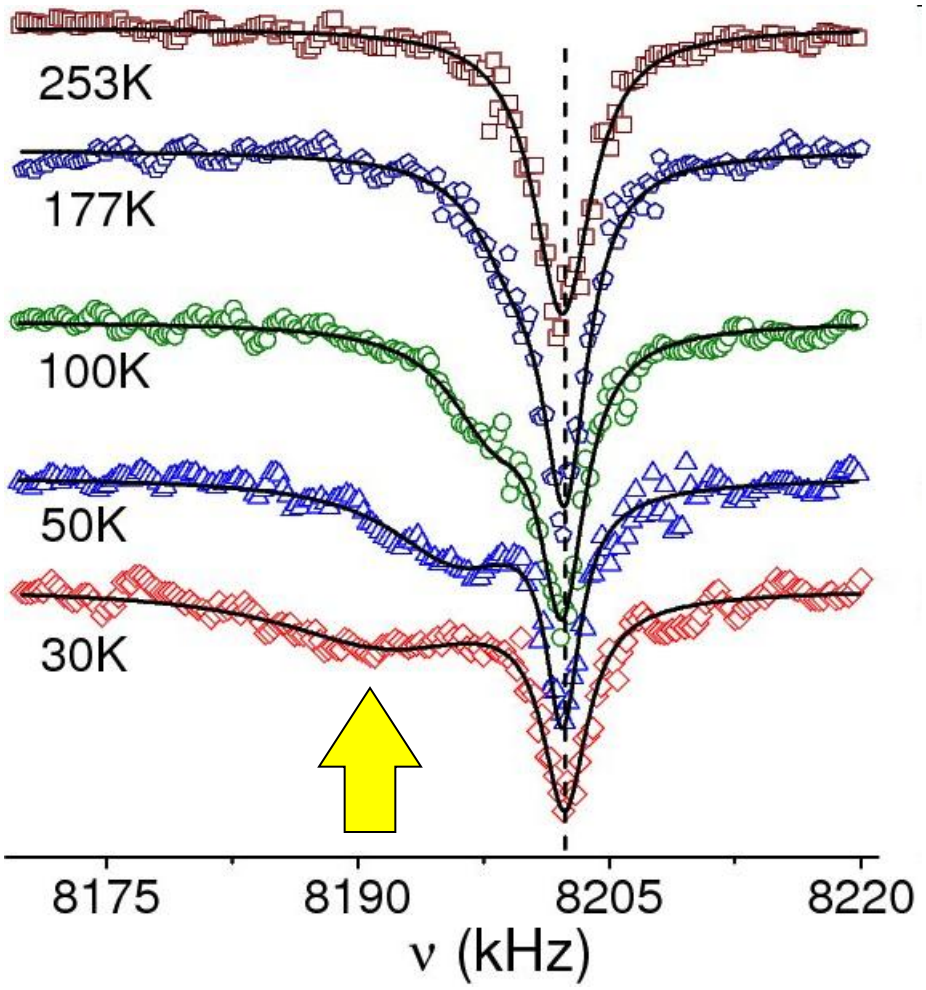




broad, negatively shifted line,
fast spin relaxation associated
with the Mn doped layer

Temperature Dependence

Pulsed rf resonances



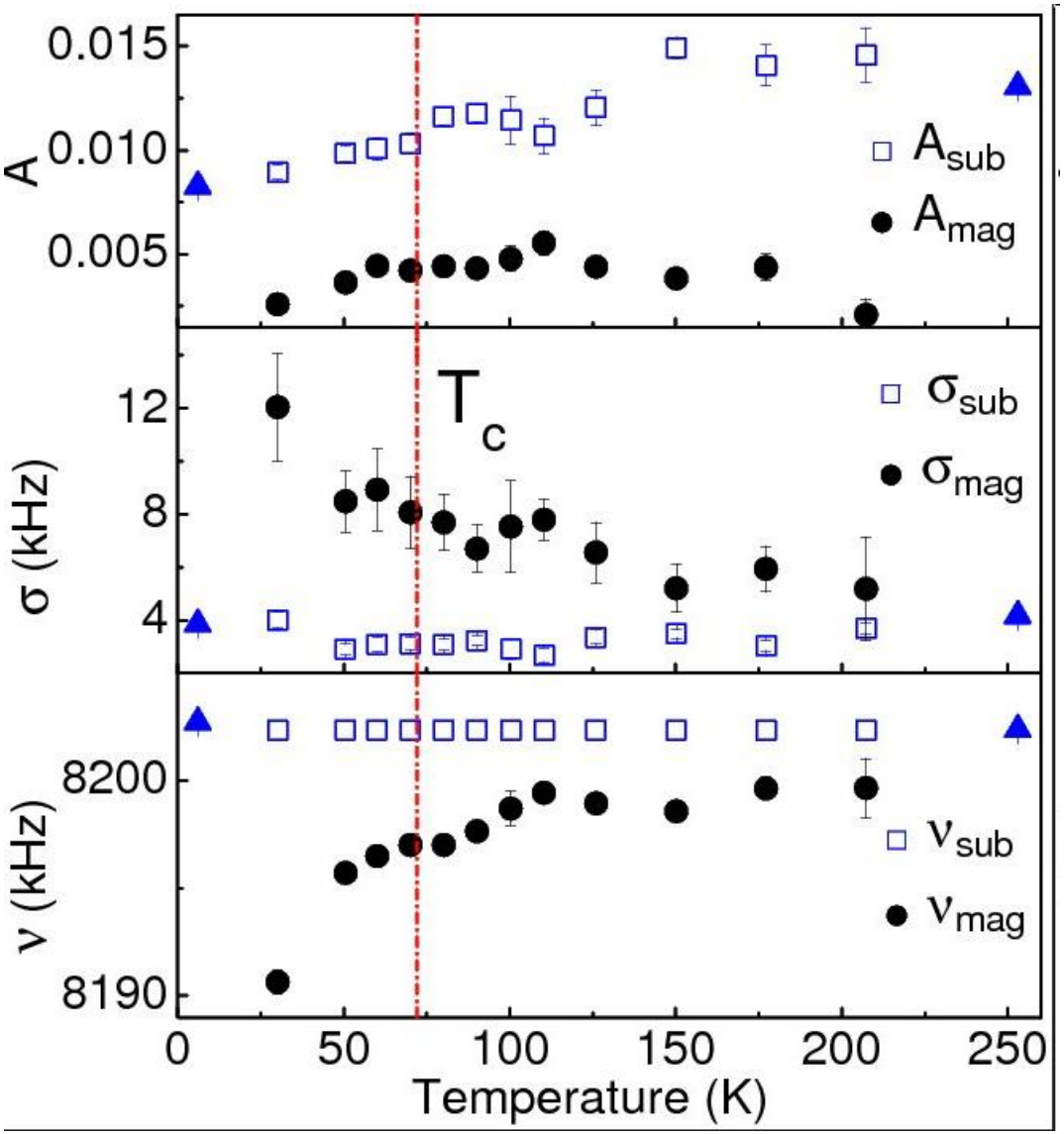
Q. Song et al., submitted to PRB

Summary of the T dependence

Lorentzian amplitude

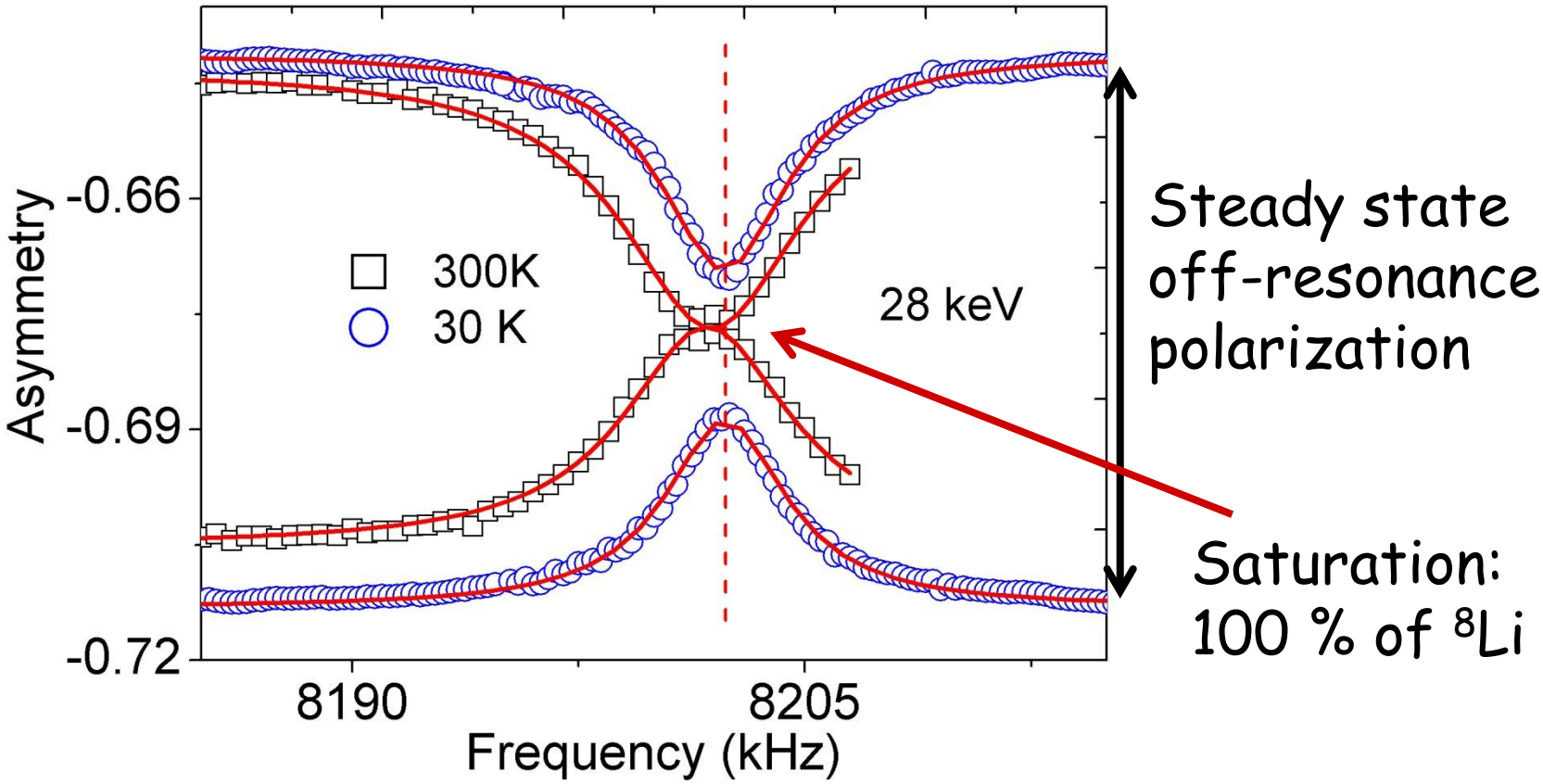
linewidth

resonance position



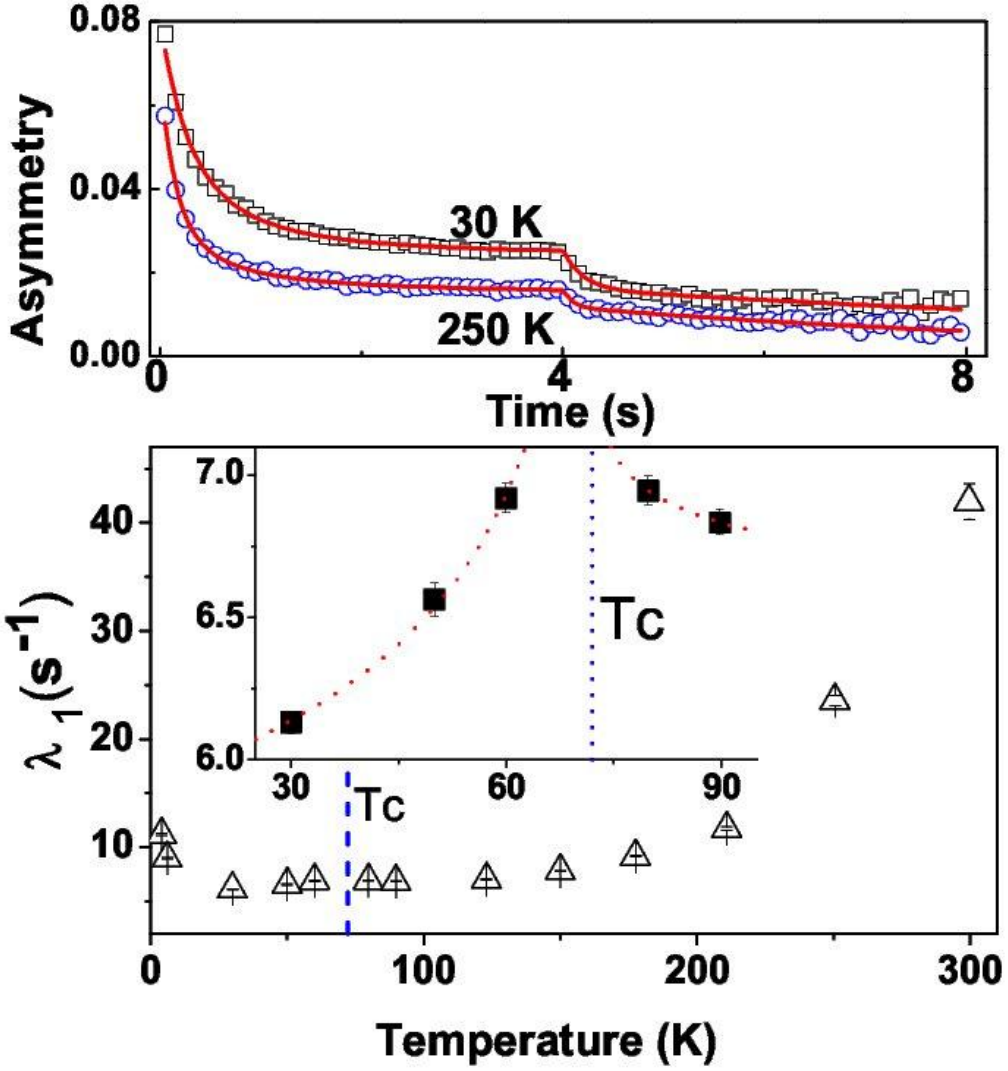
Q. Song et al., submitted to PRB

CW resonances at 28 keV



^{8}Li in GaAs substrate

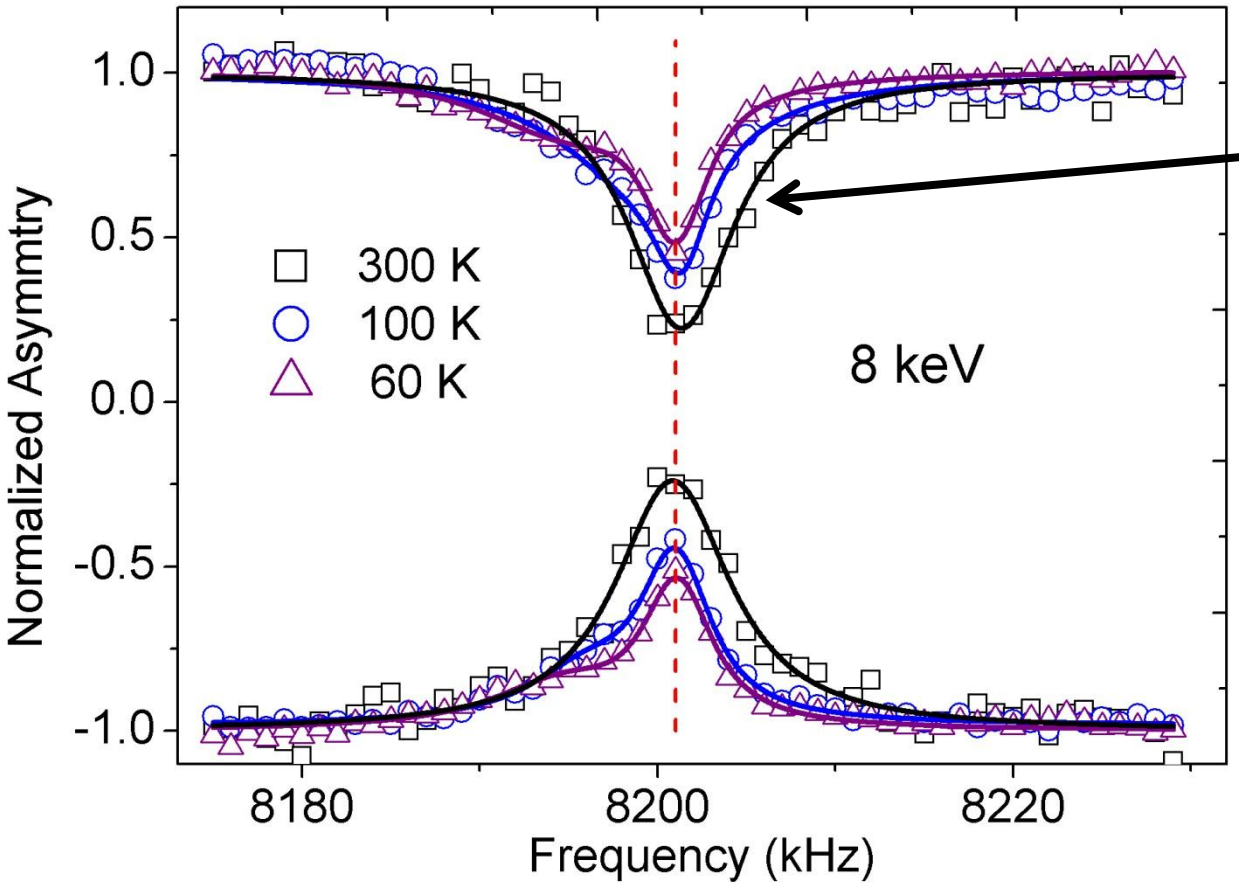
Temperature dependence of T_1



Affects resonance amplitude

Q. Song et al., submitted to PRB

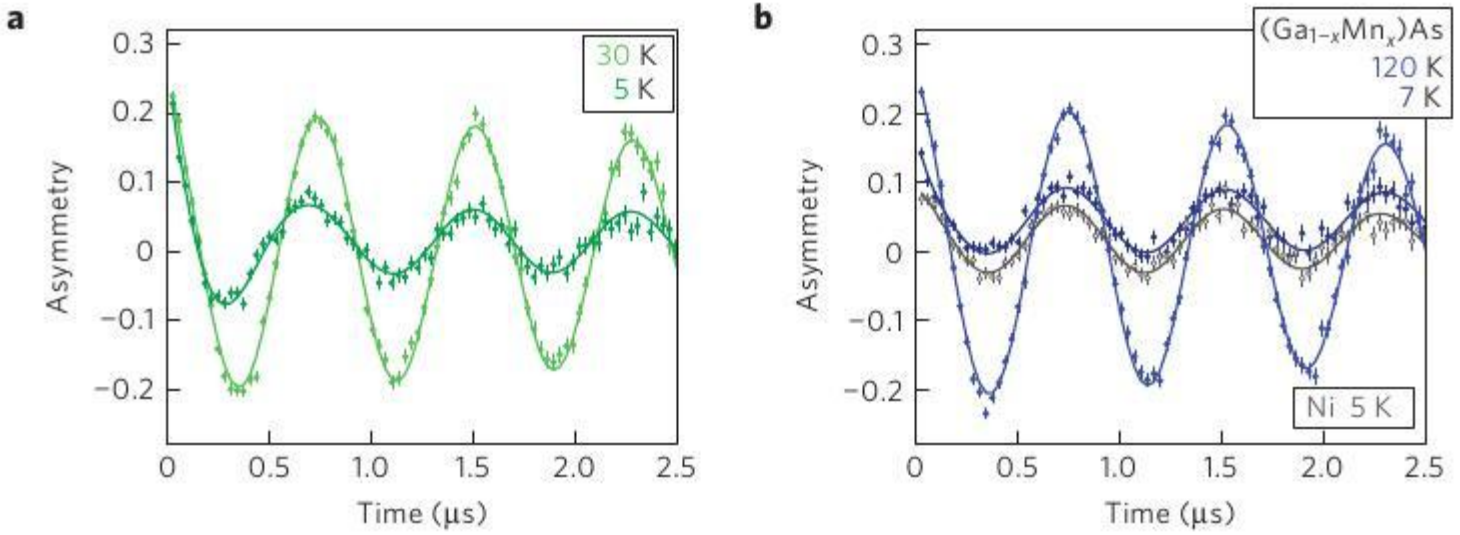
CW resonances at 8 keV: ^{8}Li in the GaAs:Mn



Incomplete saturation – disordered sites (broad line?)

No big change through Tc

LEmuSR: nonrelaxing Signal is Background

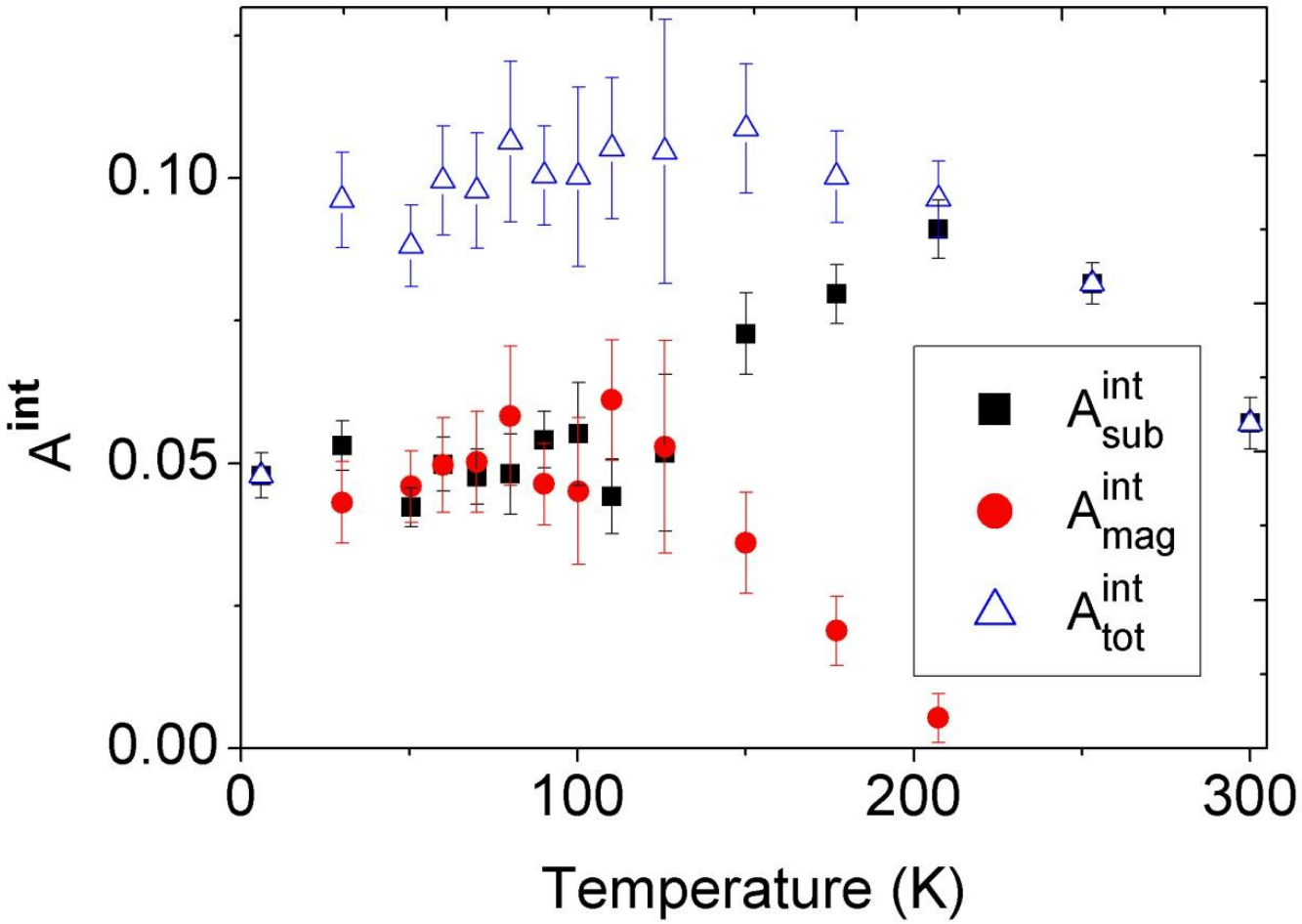


GaAs:Mn

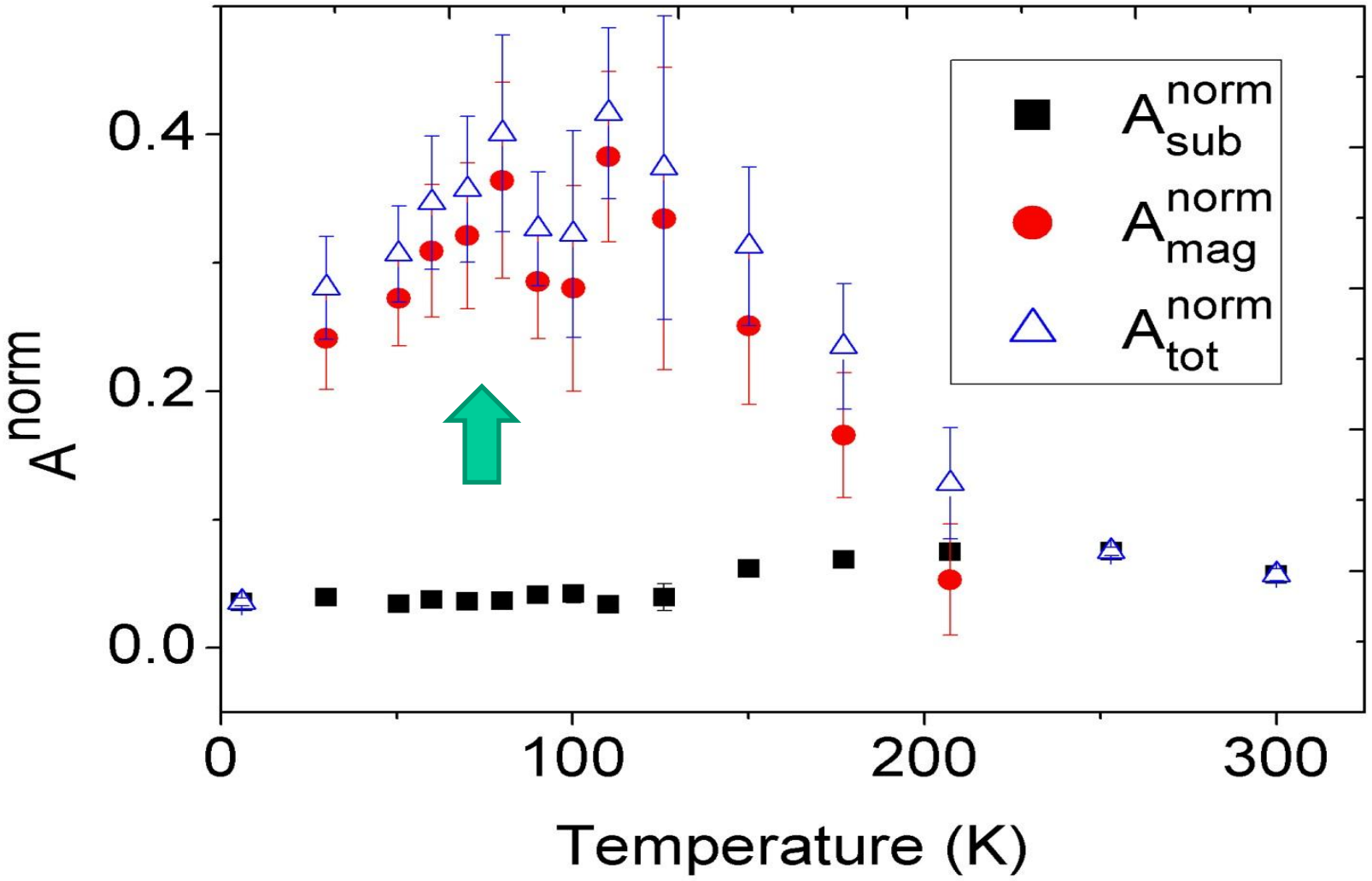
Similar sized Nickel blank

Dunsiger et al., Nature Materials **9**, 299 (10)

Pulsed Spectra Freq. Integrated Amplitudes



T_1 Scaled Amplitudes



Summary

- ßNMR surprise: a signal in a disordered magnet!
- Volume fractions not as direct as µSR but estimates possible
- No evidence for magnetic phase separation in this $GaMn_{0.054}As$
- Spin injection: from Fe? from CP light?

bnmr.triumf.ca

Acknowledgments

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S.R. Dunsiger (TUMunich)

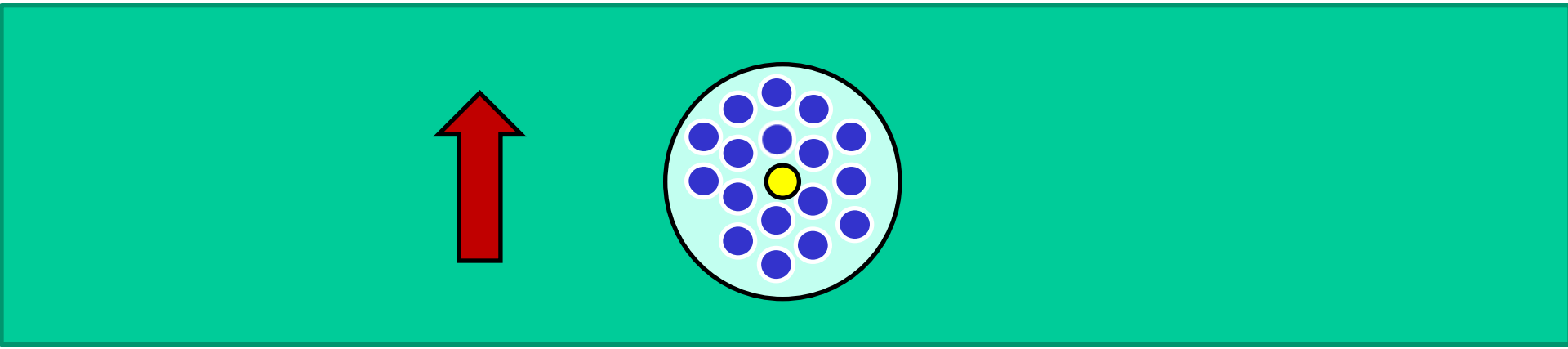
SAMPLES:

J.K. Furdyna, X. Liu (Notre Dame), K.M. Yu (Berkeley)

***now at PSI**

At TRIUMF:
Polarizer: C.D.P. Levy, M. Pearson, A. Hatakeyama (Tokyo)
RF: S.R. Kreitzman

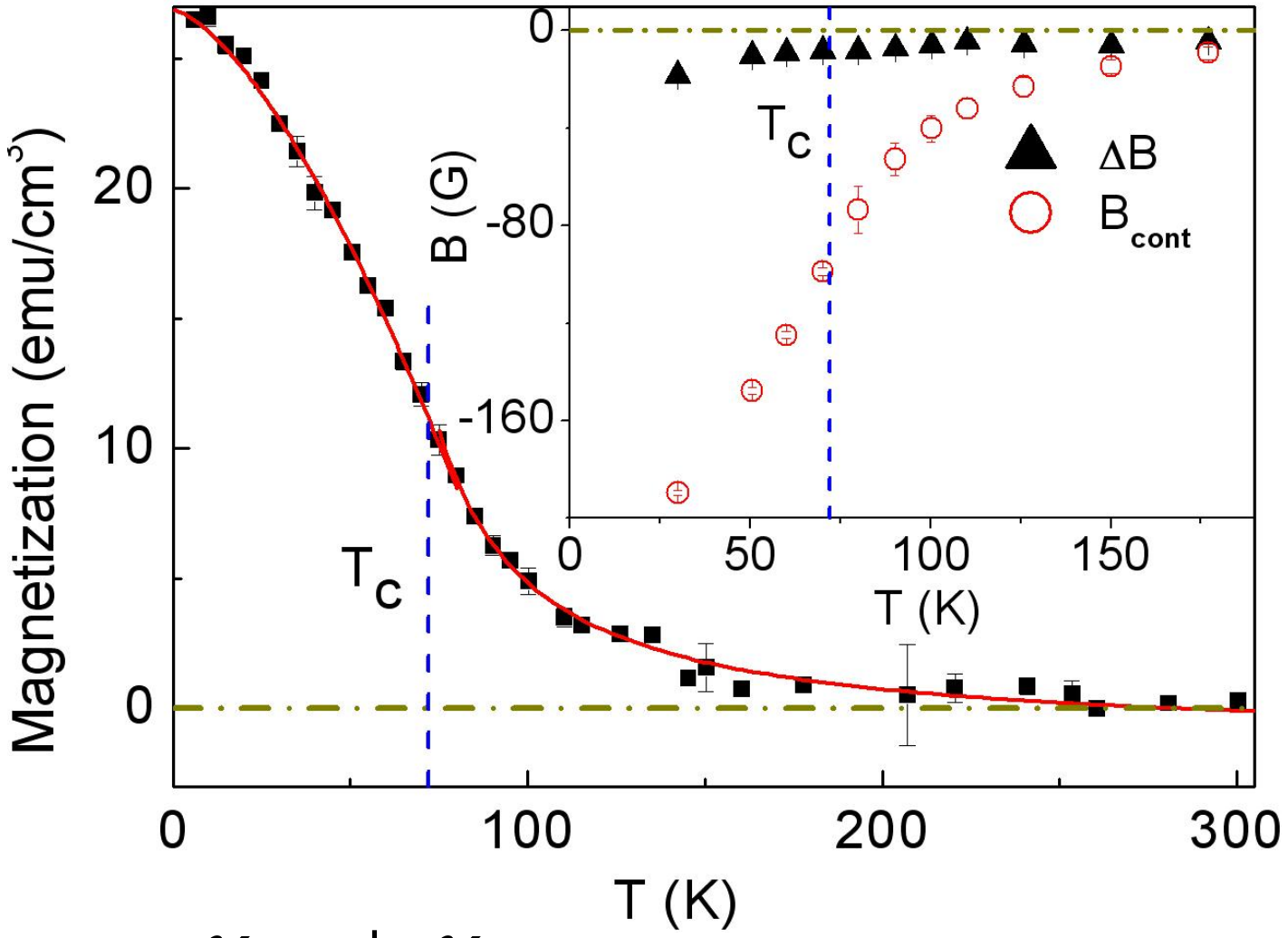
Contributions to the Local Field



$$B = B_0 + B_{demag} + B_{Lor} + B_{loc}$$

$$= B_0 - 4\pi M + (4\pi/3)M + B_{loc}$$

SQUID Magnetization in 1.3 T



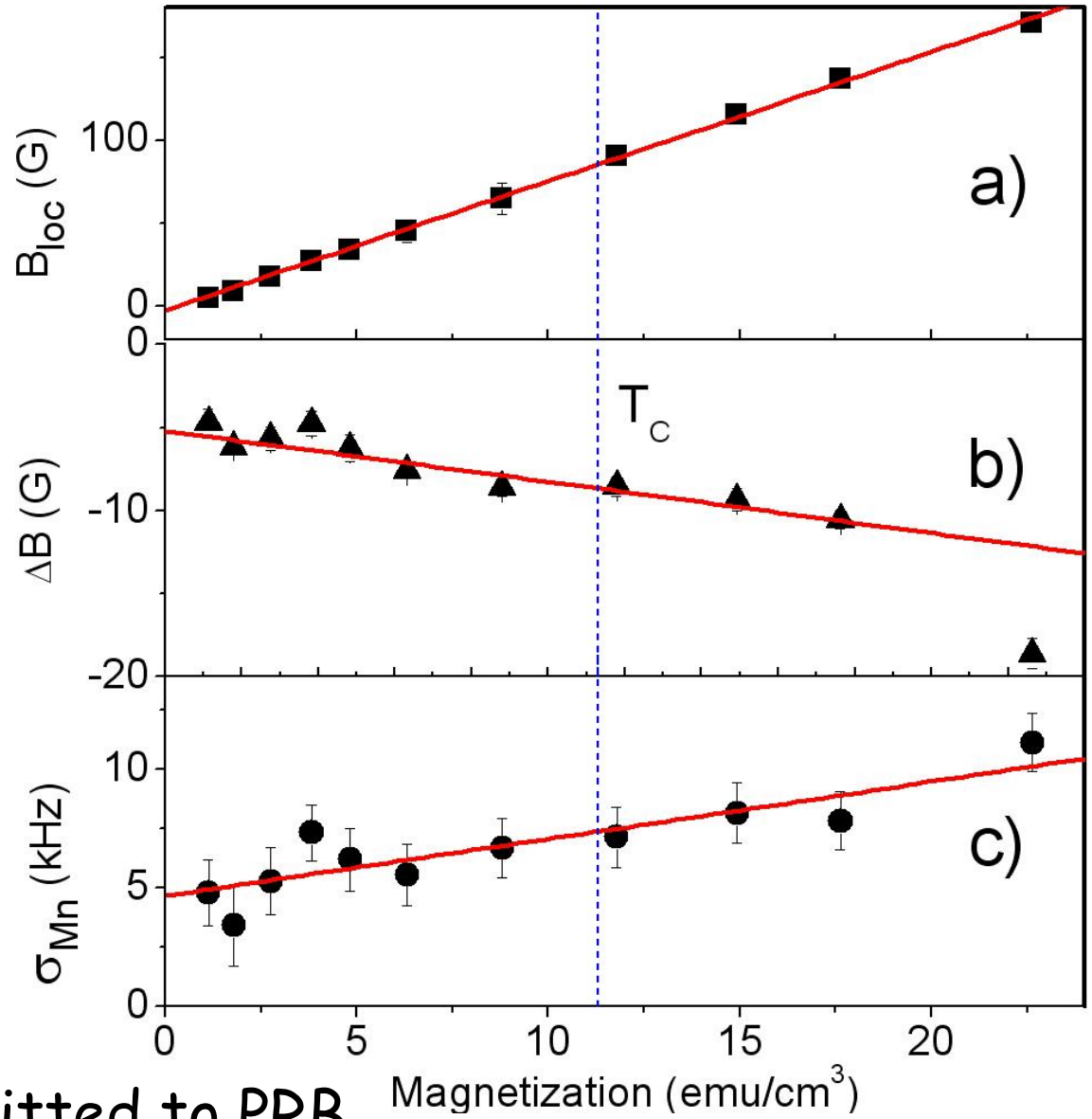
$$\chi_{GaMnAs} = \chi_{Mn} + \chi_{holes}$$

Clogston Jaccarino Analysis

The local field

raw resonance shift

linewidth



Q. Song et al., submitted to PRB