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# Titanium Vanadium – A spin fluctuation superconductor?

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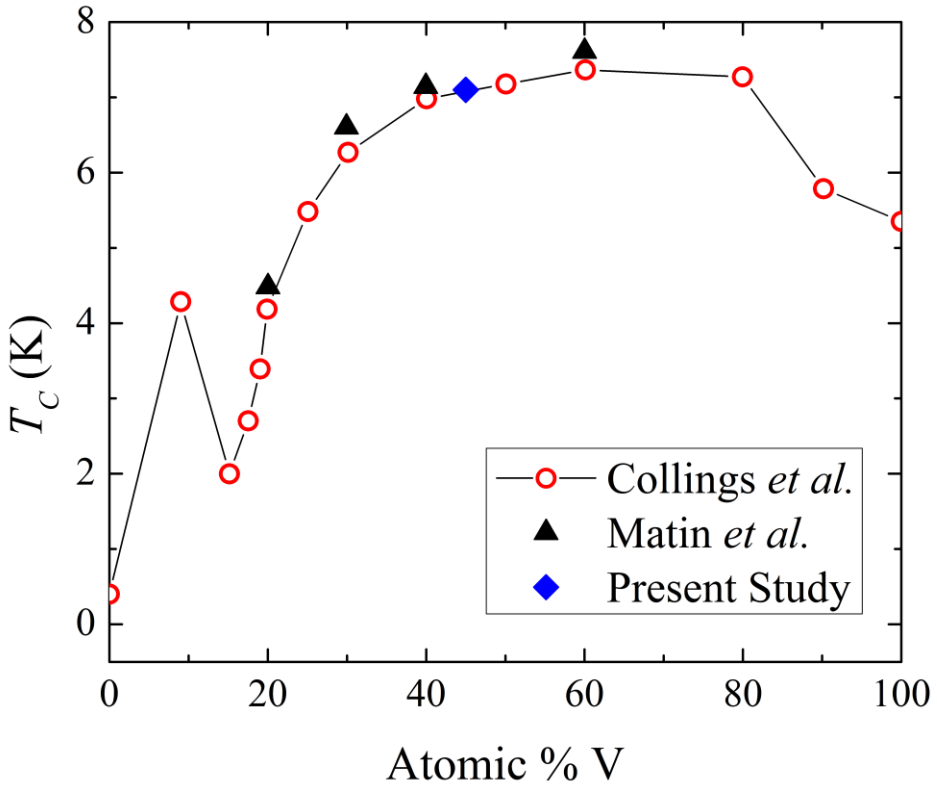
# Unusual superconductivity in Ti-V alloys

- $T_C$ of Ti-V alloys much lower than predicted under the McMillan formalism

$$T_C = \frac{\theta_D}{1.45} \exp\left\{-1.04 \frac{1+\lambda^{\mathrm{ep}}}{\lambda^{\mathrm{ep}} - \mu^* - 0.62\,\lambda^{\mathrm{ep}}\mu^*}\right\}$$

- Evidence for coexistence of spin fluctuations and the superconducting state

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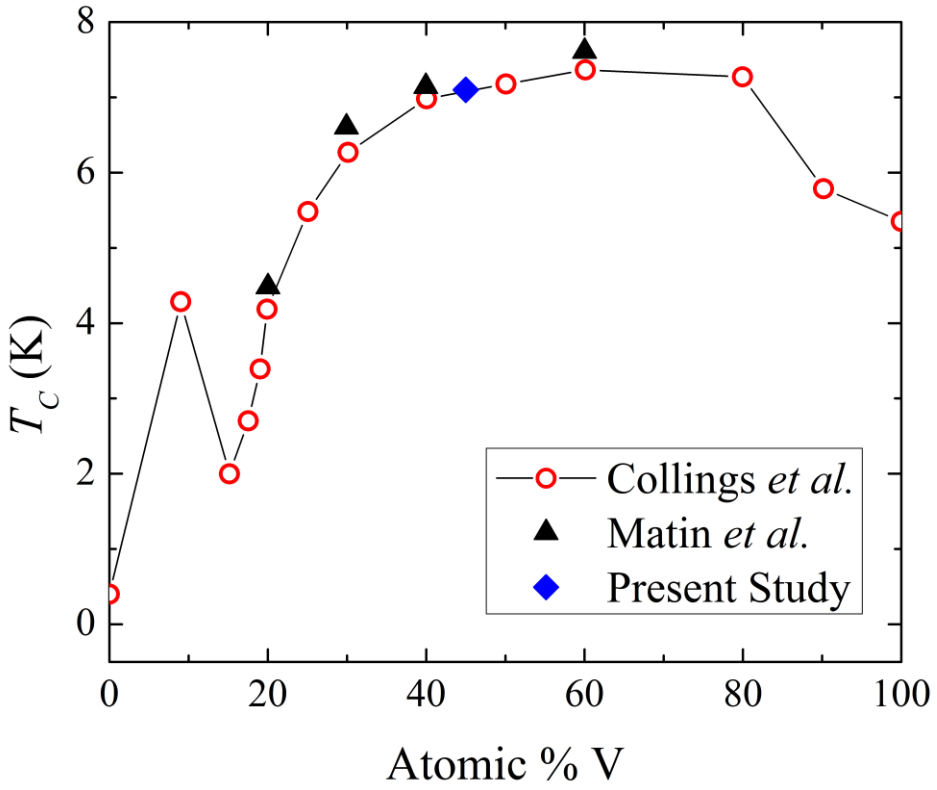
Matin *et al.*, Eur. Phys. J. B, **87**, 131 (2014)
E. W. Collings *et al.*, J. Less. Comm. Met **42**, 285 (1975)

# Unusual superconductivity in Ti-V alloys

- Can we directly observe effects of spin fluctuations?
  - Yes, with muons
- How do they influence the superconductivity?
  - Unconventional spin fluctuation mediated superconductivity
  - Conventional pairing mechanism suppressed by spin fluctuations

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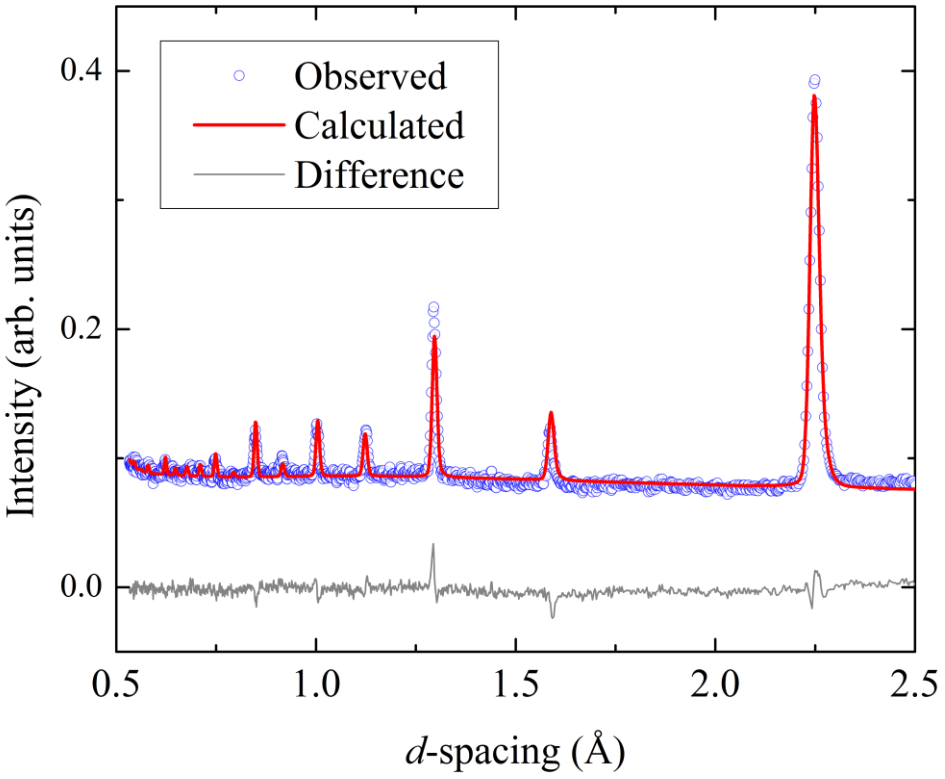
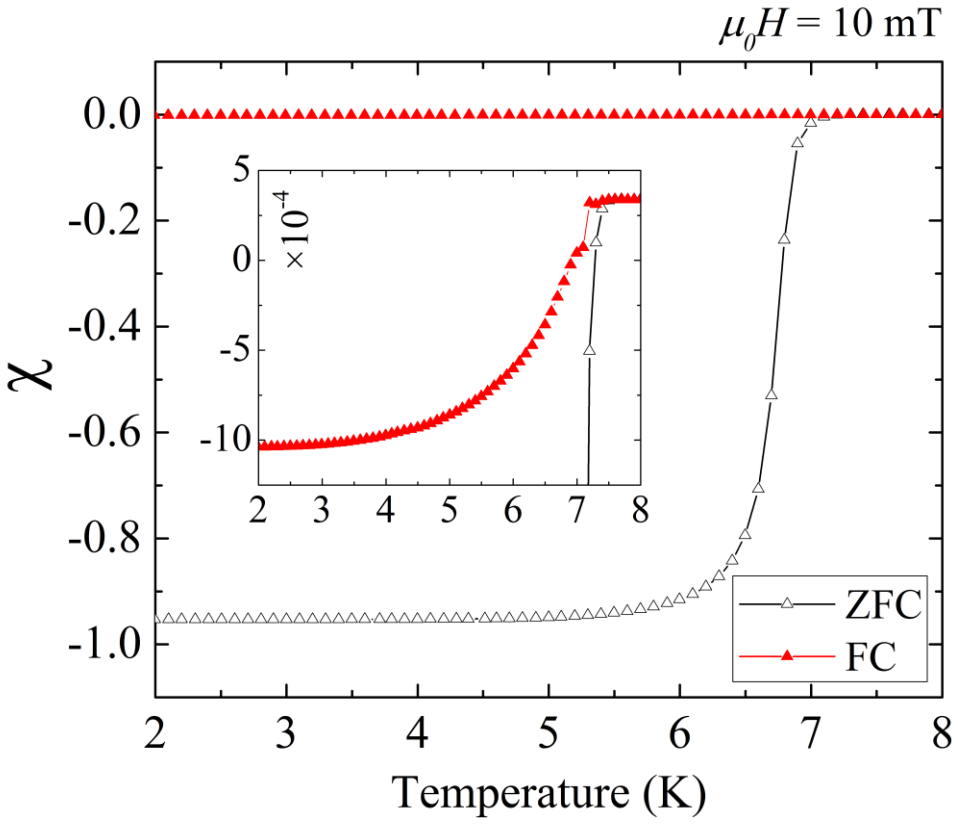
# Synthesis & Characterization




- $Ti_{55}V_{45}$
- $a$ = 3.1761(1) Å
- $T_C$ = 7.1 K

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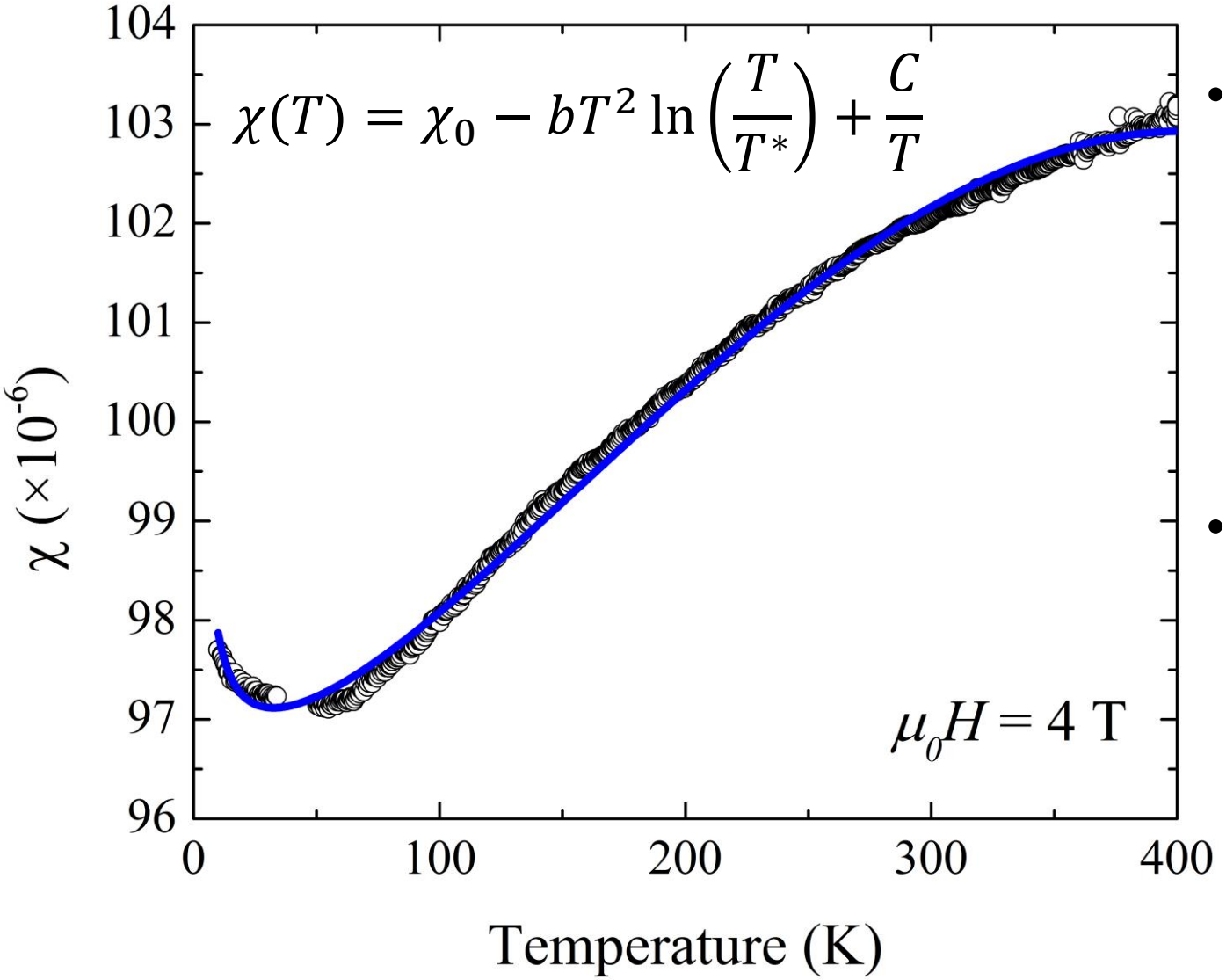


- **Low T:** Curie-Weiss paramagnet (attributed to impurities)
- **High T:** “temperature induced magnetism”

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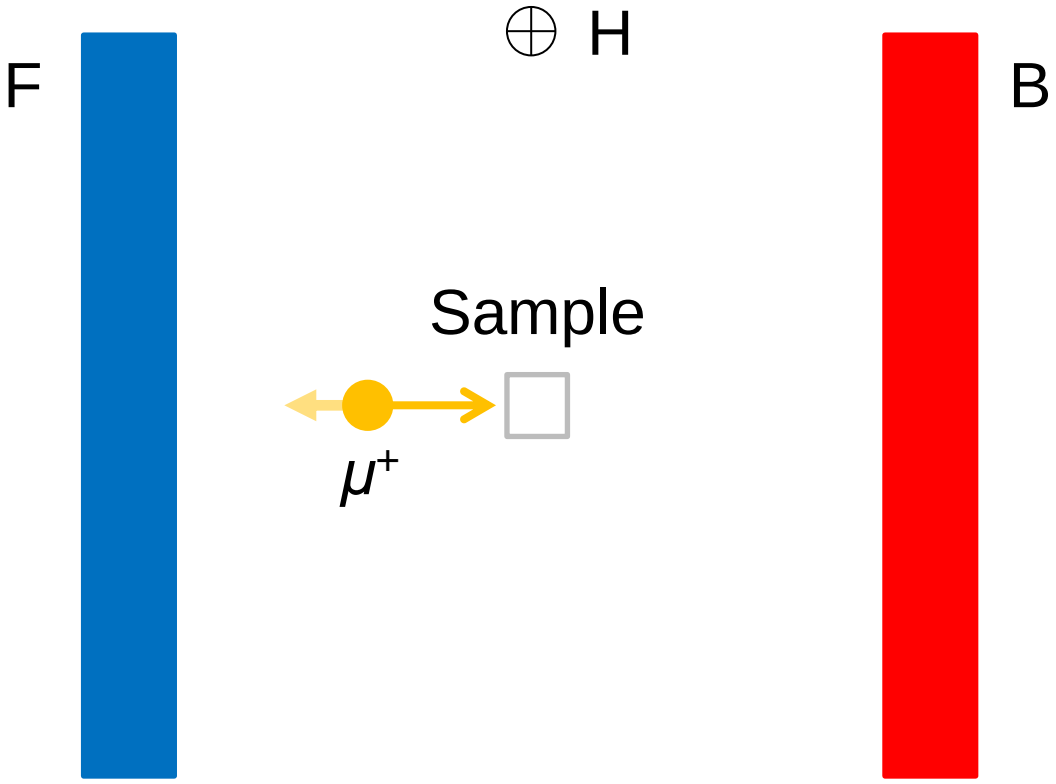
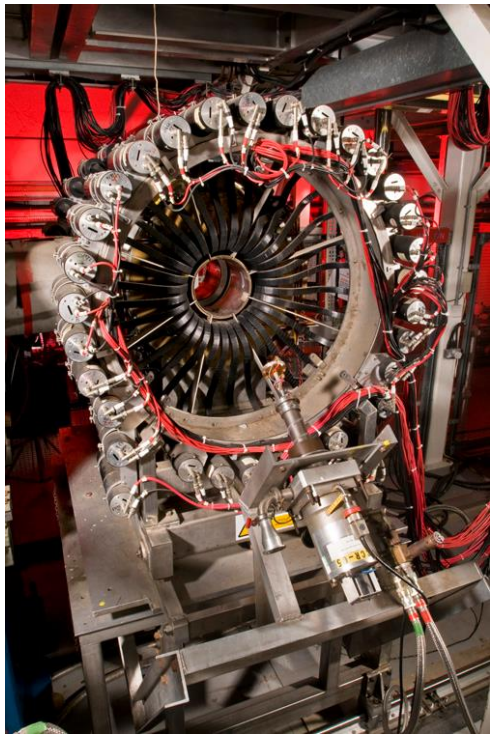
# Muon Spin Spectroscopy



MuSR instrument at ISIS

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# Zero-field μSR

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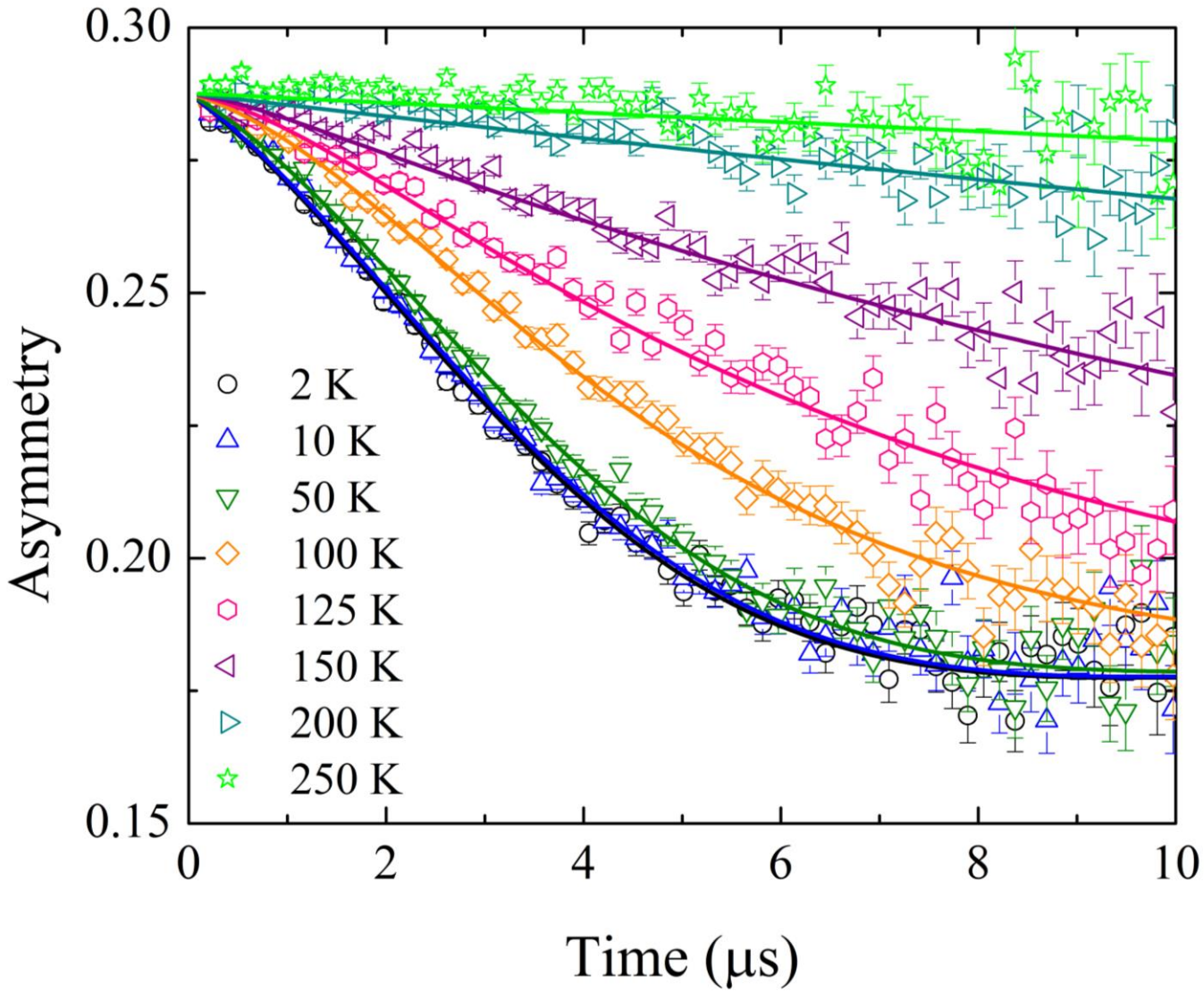


- Dynamic Kubo-Toyabe relaxation function with three relaxation components

$$G(t) = G_{DKT}(\Delta, \nu, t)e^{-\Lambda t}$$

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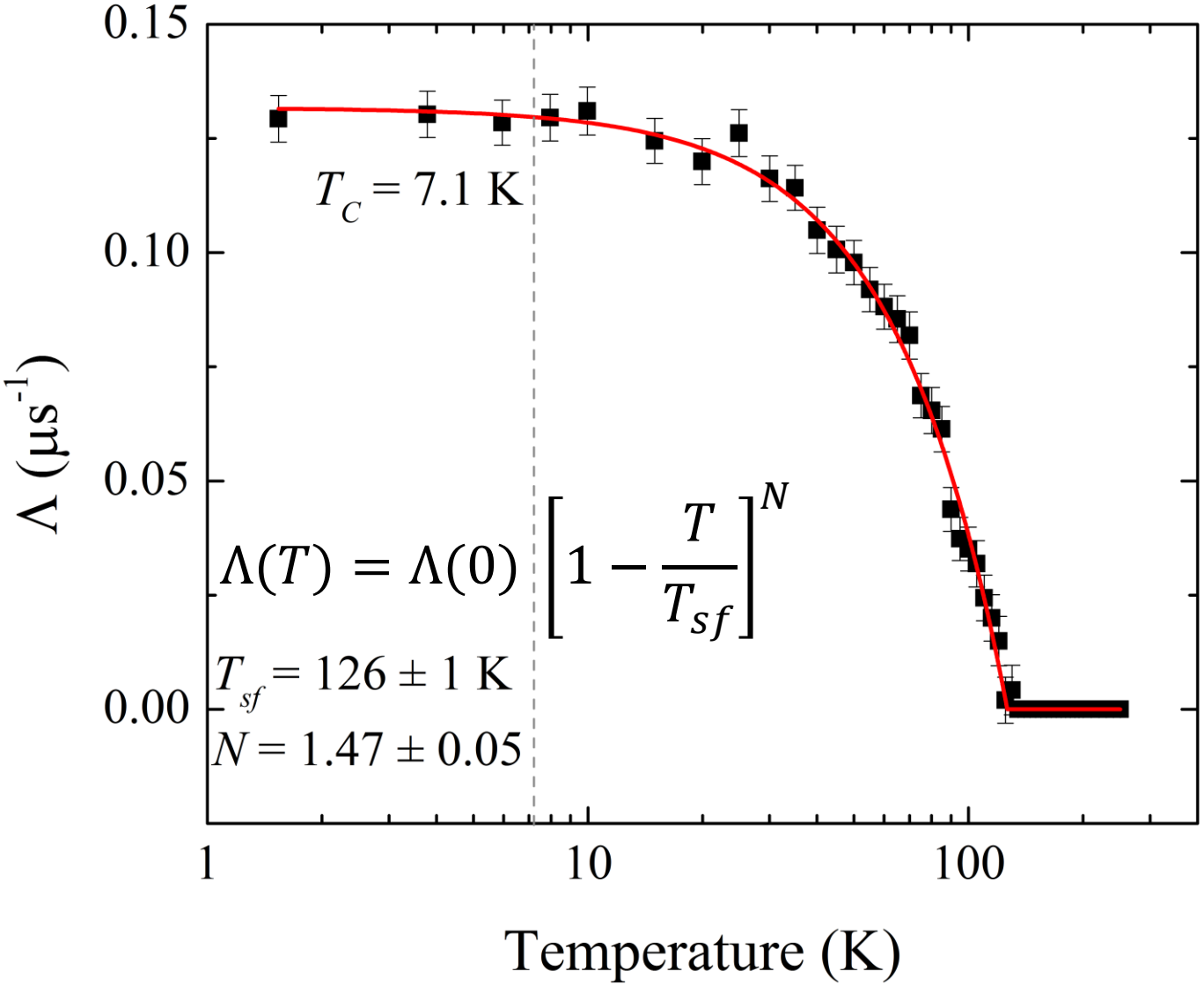


- Temperature dependence of quasi-static fluctuation component in ZF spectra fits

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# Transverse-field μSR

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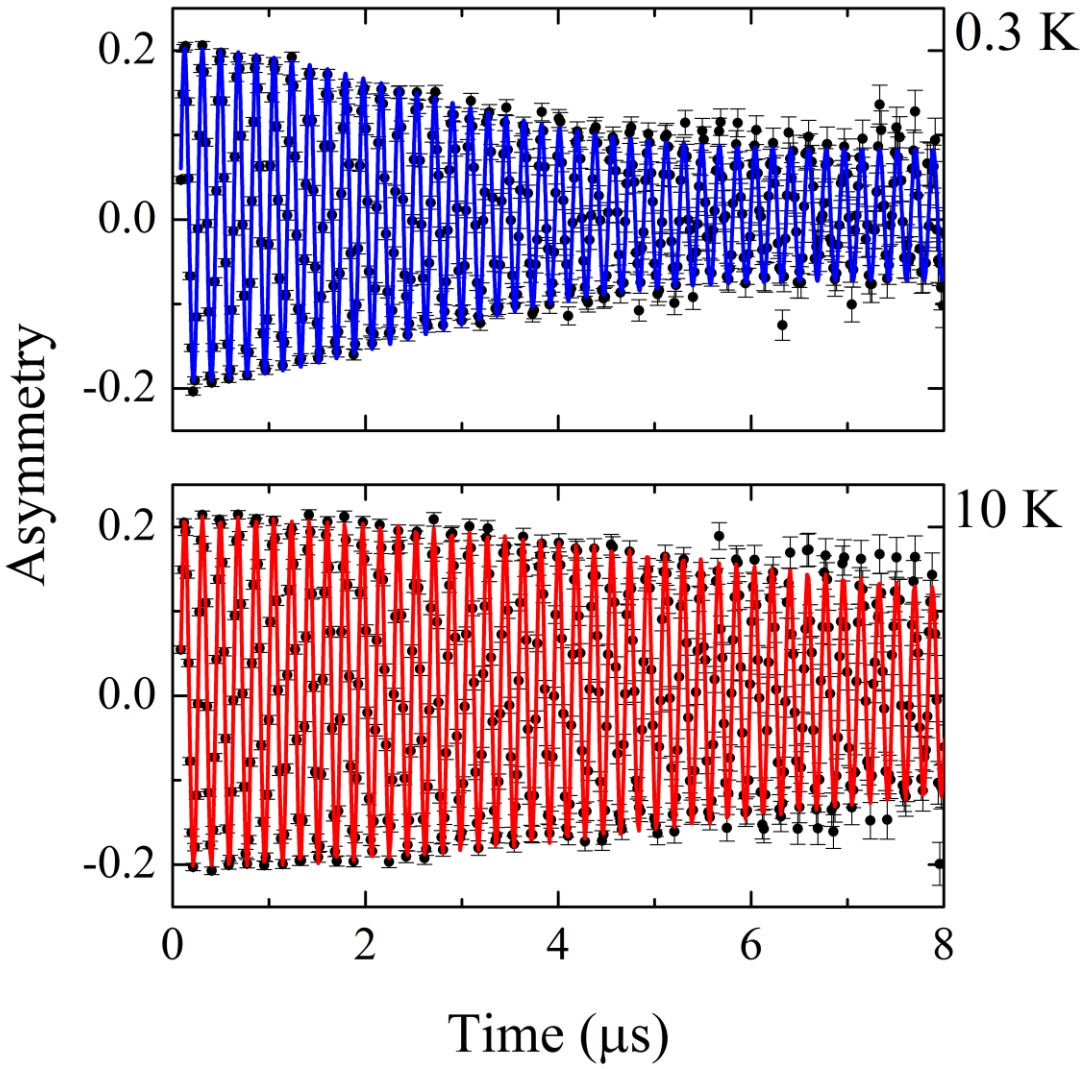


- Below $T_C$: characteristic depolarization rate caused by the vortex lattice
- Above $T_C$: small residual depolarization rate from randomly oriented nuclear spins

$$A(t) = A_1 \cos\left(\gamma_\mu B_1 t + \phi\right) e^{-\frac{1}{2}\sigma^2 t^2} + A_2 \cos\left(\gamma_\mu B_2 t + \phi\right)$$

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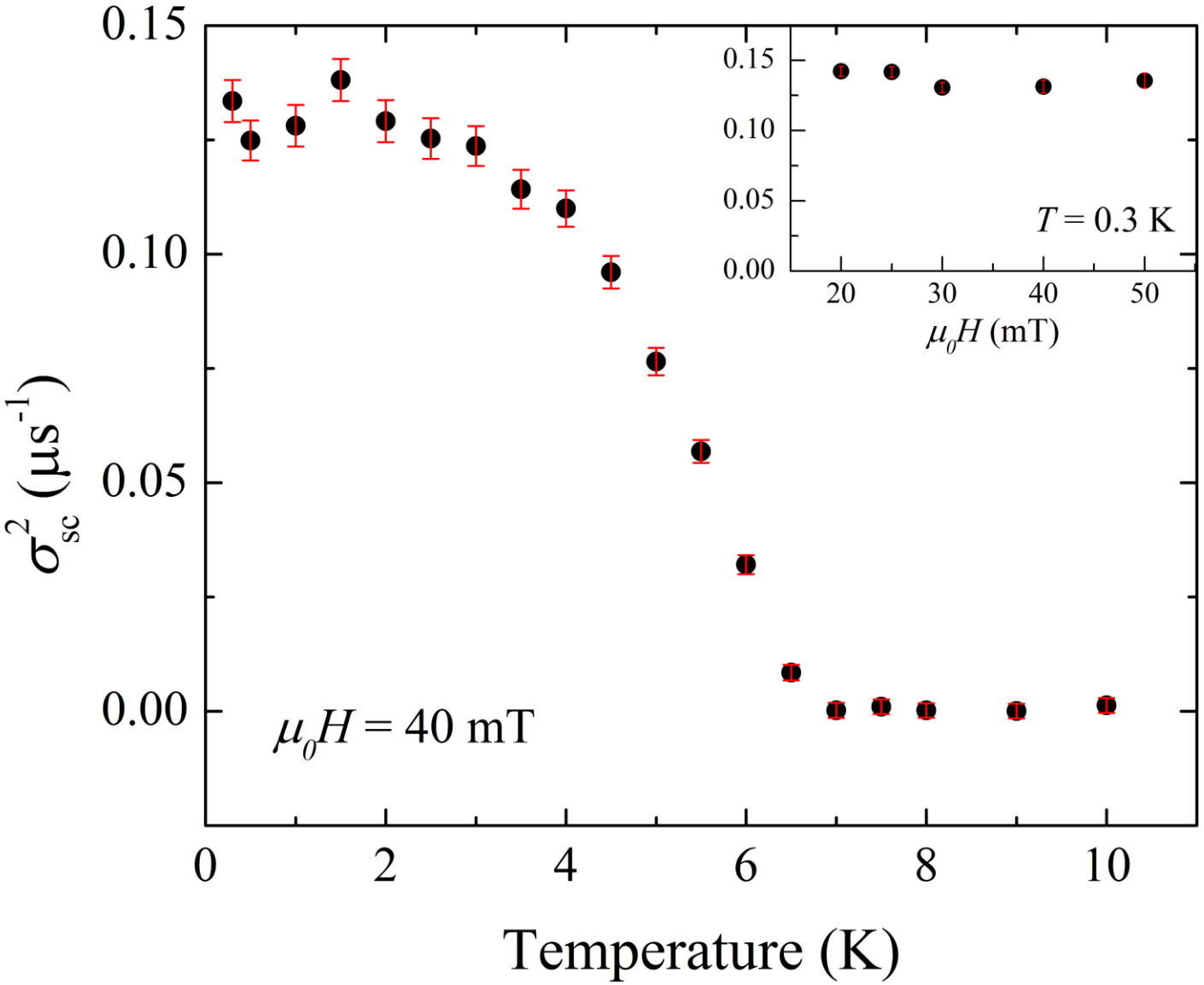


Temperature dependence of depolarization rate due to the vortex lattice determined from the experimental measurements

$$\sigma_{sc}{}^2 = \sigma^2 - \sigma_{bg}{}^2$$

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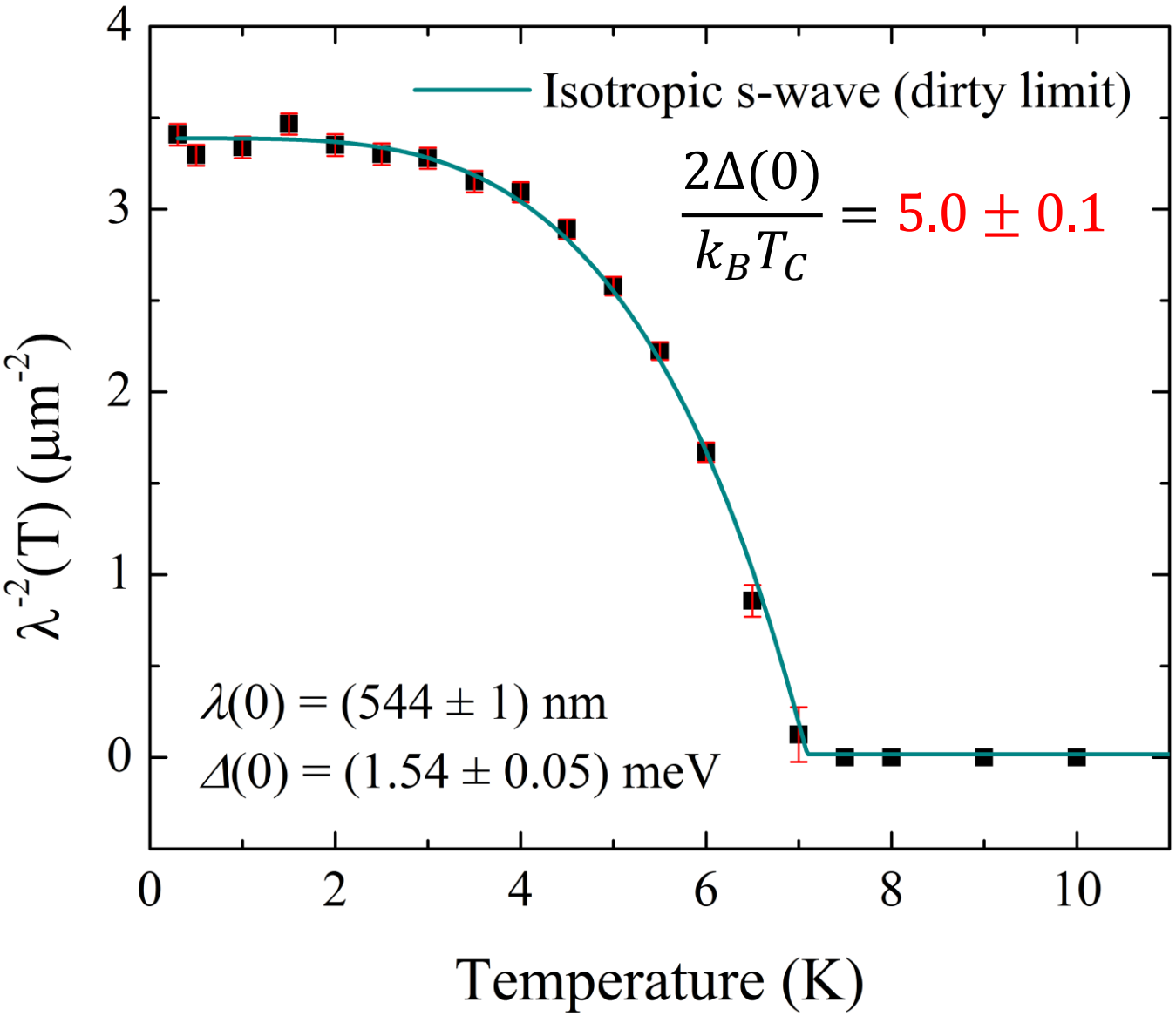


- Temperature dependence of penetration depth found directly from depolarization rate (low reduced-field limit)

$$\frac{{\sigma_{sc}}^2}{\gamma_\mu} = 0.00371 \frac{{\Phi_0}^2}{\lambda^4}$$

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# Conclusions

- First direct observation of spin fluctuations in a Ti-V system, with onset temperature of 126 K
  - What changes at 126 K causing the onset of spin fluctuations?
- Temperature dependence of the penetration depth fits an isotropic s-wave BCS model in the strong coupling limit
  - What role do the spin fluctuations play in the superconducting mechanism?

# Acknowledgements

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