# Pressure-driven Antiferromagnetic Quantum Phase Transition

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## Abstract

My project focuses on the pressure-driven antiferromagnetic quantum phase transition in pure Cr metal. This is a model system for studying the effects of quantum fluctuations on an itinerant antiferromagnet. Elemental chromium orders antiferromagnetically near room temperature, but the ordering temperature can be driven to zero either by doping or applying large pressures. Such zero-temperature quantum phase transitions (QPT) are driven by quantum fluctuations, in contrast to the more familiar thermal fluctuations at finite temperature transitions. Previous studies on vanadium-doped Cr have demonstrated that the Hall coefficient is an unusually sensitive probe of the QPT[1].

My project is to drive the phase transition with pressure rather than doping while using the Hall coefficient as a probe of quantum critical fluctuations in carrier density. This work will complement ongoing measurements in our group on the spin and charge order at the pressure-driven QPT[2, 3].

## Outline

### Instrument Development

The main aspect of the project is to build a Hall effect measurement system compatible with an existing cryogenic pressure cell. This involves plumbing a conventional, water-cooled electromagnet, adapting its pole pieces to higher field requirements, working with the JFI electronics shop to adapt an existing electromagnet power supply to a computer-controlled Hall configuration, designing and machining a mechanical mount between the magnet and the cryostat, and developing the control software needed for the measurements.

### Hall Coefficient Measurement

With the instrumentation complete, this system will allow measurement of the Hall coefficient $R_H$ as a function of pressure & temperature. Applying a magnetic field $B$ to a sample with current density j gives rise to a voltage $V_H \propto B \times j$. This Hall voltage varies linearly with applied field, and the slope is the Hall coefficient which (within a single-band Drude model) varies inversely with the charge carrier density. The current and voltage measurements will be made using an AC resistance bridge, and the preparation of single crystal Cr samples for electrical transport measurements is well established in our group. We will measure $R_H(P, T)$ in the elemental antiferromagnet Cr, looking for signatures of the transition from the antiferromagnetic to paramagnetic state in the quantum regime. We will also compare our results with analogous data on the vanadium-doping driven QPT, with the hope of identifying the effects of chemical substitution on metallic quantum criticality.

## Conclusion

I have been working on the construction of the measurement system for several months. Once complete, it will allow measuring $R_H(P, T)$, and accessing the physics of a QPT in a metallic antiferromagnet. The key physical parameter is the critical exponent characterizing the change in carrier density as the spin-density-wave gap closes at the quantum critical point, which should then be compared to what was seen as a function of doping in the $Cr_{1-x}V_x$ family[4]. This will be a sensitive tool, in company with existing scattering and longitudinal resistivity techniques.

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