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Experiments in spin-polarized Fermi gases– pairing without superfluidity?[1]

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Fermionic superfluidity requires pairing of fermions. The nature of fermionic pairing in the strongly interacting regime both in the superfluid and possibly in the normal phase is of interest to condensed matter, nuclear and high energy physics. The experimental realization of high temperature superfluidity in ultracold Fermi gases opens a new approach to explore strongly interacting fermions both in the superfluid and normal phases. One question of relevance for example to superfluidity of quarks in cold baryonic matter as well as superconductivity has been the stability of the superfluid against an imbalance between the two strongly interacting fermionic components. An imbalance can be caused by different masses of the fermions or an externally applied magnetic field to a superconductor. In our experiments a density imbalance between two fermionic spin components is introduced. We will present the phase diagram of a spin-polarized Fermi gas of 6Li atoms at unitarity, mapping out the superfluid phase versus temperature and density imbalance. The nature of the phase transition changes from first-order to second-order at a tricritical point. At zero temperature, there is a quantum phase transition from a fully-paired superfluid to a partially-polarized normal gas at a critical spin polarization, known the Chandrasekhar-Clogston limit of superfluidity. These observations together with the implementation of an in situ ideal gas thermometer provide quantitative tests of theoretical calculations on the stability of resonant superfluidity. Pairing correlations in the superfluid and normal phases were explored in radio-frequency spectroscopy experiments. We studied how pairing correlations evolve across the superfluid to normal phase transition both as a function of temperature and spin imbalance. Even at spin imbalances above the Chandrasekhar-Clogston limit a gap in the single-particle excitation spectrum is observed. This indicates that the system is in a correlated state and the minority component is paired. The influence of final state interactions on the rf spectra will be discussed. Using a new superfluid 6Li spin mixture we demonstrate that pair dissociation spectra in the BEC-BCS crossover resemble asymmetric molecular dissociation spectra. Work done in collaboration with Y. Shin, A. Schirotzek and W. Ketterle, Department of Physics, MIT-Harvard Center for Ultracold Atoms, and Research Laboratory of Electronics, MIT, Cambridge, MA 02139.

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