Pseudogap state of (Bi,Pb)2201 studied by muon Knight shift

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Despite decades of focused research using almost every experimental technique available to date, the microscopic origin of pseudogap in cuprates is still elusive. One of the problems in gaining a coherent understanding of the pseudogap is that the reported results disagree with each other, where the arbitrary definition of the gap energy or characteristic temperature (T^*) entails further confusion. The muon Knight shift (K_μ) is a direct measure of the electronic density of states (DOS) probed at the interstitial site, comprising information complementary to NMR. In this contribution, we report on K_μ measurements performed in single crystals of $Bi_{1.74}Pb_{0.38}Sr_{1.88}CuO_{6+\delta}$ [(Bi,Pb)2201] over a wide range of carrier doping covering both ends of the superconducting phase (the dome of T_c), where doping was controlled by excess oxygen to minimize the perturbation to CuO_2 planes. The magnitude of pseudogap, defined as an activation energy of the Arrhenius type, was deduced from the temperature (T) dependence of K_μ for each sample. The remarkable results are that, 1) the pseudogap is clearly inferred from reduction of K_μ ($\propto$ DOS) at low temperatures in the non-superconducting sample situated in the overdoped region, 2) a residual K_μ is observed at low temperatures with the magnitude depending on the doping concentration.