 MLF Experimental Report	提出日 Date of Report 2017. 4. 10
課題番号 Project No. 2105A0199 実験課題名 Title of experiment μ SR study of Cu-spin fluctuations in the heavily overdoped T' - $\text{Pr}_{1.3-x}\text{La}_{0.7}\text{Ce}_x\text{CuO}_{4+\delta}$ ($x = 0.15 - 0.25$) single crystals 実験責任者名 Name of principal investigator Tadashi Adachi 所属 Affiliation Department of Engineering and Applied Sciences, ophia University	装置責任者 Name of responsible person Yasuhiro Miyake 装置名 Name of Instrument/(BL No.) D1 実施日 Date of Experiment 2016. 6. 6 - 9

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。(適宜、図表添付のこと)
 Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form. Electron-doped high- T_c T' -superconductors $\text{Pr}_{1.3-x}\text{La}_{0.7}\text{Ce}_x\text{CuO}_{4+\delta}$ Moderately reduced and over-reduced single crystals

2. 実験方法及び結果 (実験がうまくいかなかった場合、その理由を記述してください。) Experimental method and results. If you failed to conduct experiment as planned, please describe reasons. Zero-field and longitudinal-field μ SR measurements were performed using the MiniCryo at temperatures between 200 K and 3 K and in magnetic fields up to 500 G for moderately reduced (the superconducting transition temperature $T_c = 25$ K) and over-reduced ($T_c = 25$ K) single crystals of $\text{Pr}_{1.3-x}\text{La}_{0.7}\text{Ce}_x\text{CuO}_{4+\delta}$ with $x = 0.10$. Measurements were performed in the double-pulsed mode. For the moderately reduced crystals, zero-field μ SR time spectra were Gaussian-like more or less at high temperatures, while the depolarization of muon spins becomes fast gradually with decreasing temperature due to effects of the Pr^{3+} moments. At low temperatures, the spectra show fast depolarization in the short-time region and slow depolarization in the long-time region. This two-component behavior is similar to that observed in our previous measurements of the moderately reduced $\text{Pr}_{1.3-x}\text{La}_{0.7}\text{Ce}_x\text{CuO}_{4+\delta}$ with $x = 0.10$ [1] and suggests the formation of a short-range magnetic order of Cu spins coexisting with the superconductivity.
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2. 実験方法及び結果(つづき) Experimental method and results (continued)

For the over-reduced crystals, it was found that Gaussian-like depolarization becomes fast gradually with decreasing temperature. However, no fast depolarization was observed down to 3 K, suggesting that the short-range magnetic order was not formed in the over-reduced crystals.

The spectra of the moderately reduced and over-reduced crystals were analyzed by the three-component and two-component functions, respectively [1]. Figure 1 shows the temperature dependence of the depolarization rate of muon spins λ for moderately reduced and over-reduced $\text{Pr}_{1.3-x}\text{La}_{0.7}\text{Ce}_x\text{CuO}_{4+\delta}$ with $x = 0.10$. For the moderately reduced crystals, it is found that λ exhibits a peak around 50 K, which is a typical behavior of the occurrence of a magnetic transition. For the over-reduced crystals, λ increases with decreasing temperature and tends to be saturated at low temperatures, suggesting the development of the Cu-spin correlation. These results suggest that, through the reduction annealing, the short-range magnetic order disappears and the Cu-spin correlation develops at low temperatures. Therefore, the superconductivity is probably in intimate relation with the Cu-spin correlation in the electron-doped high- T_c cuprates.

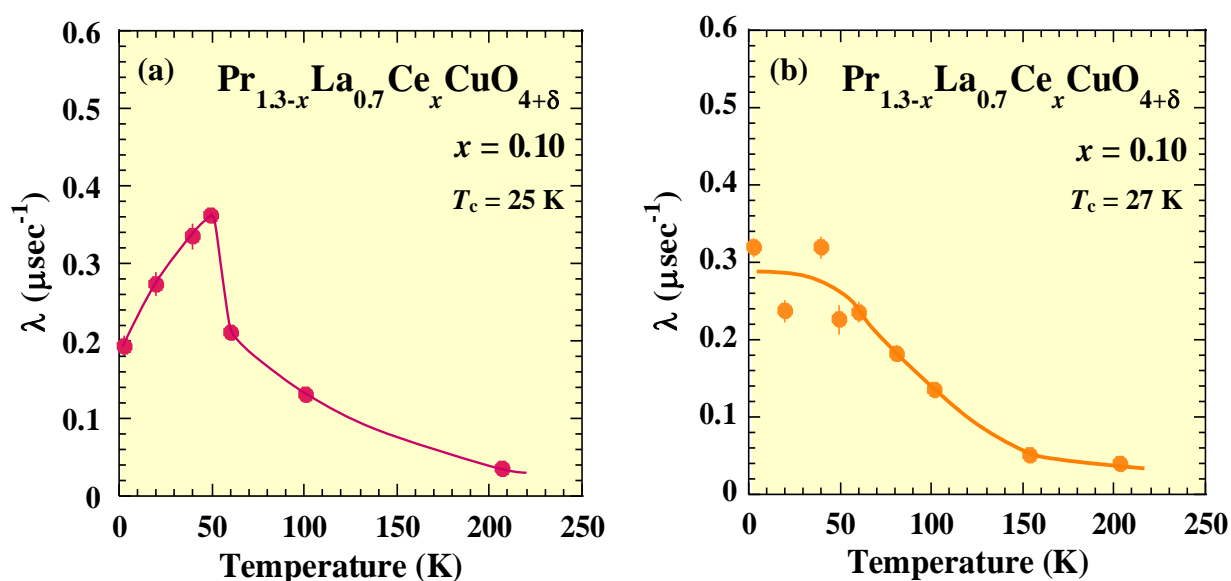


Fig. 1. Temperature dependence of the depolarization rate of muon spins λ for (a) the moderately reduced and (b) over-reduced single crystals of $\text{Pr}_{1.3-x}\text{La}_{0.7}\text{Ce}_x\text{CuO}_{4+\delta}$ with $x = 0.10$.

[1] T. Adachi, A. Takahashi, K. M. Suzuki, M. A. Baqiya, T. Konno, T. Takamatsu, M. Kato, I. Watanabe, A. Koda, M. Miyazaki, R. Kadono and Y. Koike, J. Phys. Soc. Jpn. **85**, 114716 (2016).