Magnetic Resonance Imaging (MRI) is the major clinical imaging diagnostic method. It is a well-recognized imaging modality providing spatial distribution of proton (^{1}H) density and properties of the tissues called relaxation times T_1 and T_2. The differences in these relaxation times provide contrast between healthy and diseased tissue, such as cancer. However, these differences are often insufficient to distinguish between tissues hindering diagnosis. To rectify this issue contrast agents are used. Following intravenous injection they accumulate in the tissue of interest (e.g. caner) due to its high vasculature or are delivered by biological vehicles such as antibodies. The most frequently used contrast agents are based on Gd atoms and are able to shorten only T_1 relaxation time providing so called positive contrast (tumor is brighter in MRI). Contrast agents based on iron oxide nanoparticle cans reduce T_2 relaxation time and provide negative contrast in MRI (tumor is getting darker). Recent application of so called core/shell nanoparticles, that shorten both T1 and T2, allowed new imaging techniques to be applied that provide better tissue contrast hence improved diagnostic capabilities of MRI. They are very effective relaxation enhancers allowing to employ low, thus harmless concentrations of particles to achieve significant reduction in relaxation times in targeted cells, such as tumour cells, where they accumulate. Furthermore, due to their chemical properties they can be easily biosynthesized with tumour specific antibodies and coated to reduce their toxicity.

Clinical MRI systems use magnetic field from about 0.5T to 3T, while pre-clinical (animal) system use higher magnetic fields up to 14T. The higher magnetic field the higher, so called, signal-to-noise ratio hence better image quality. The relaxation decrease caused by the core/shell nanoparticles depends on their core and shell sizes and on the magnetic field used for MRI. Unfortunately, there is a gap between very fast development of nanotechnology enabling production of nanoparticles with tailored properties and much slower progress in understanding of nuclear relaxation in the presence of nanoparticles. There is no theory that would allow to predict this effect and synthesis of the core/shell is hampered, as no one can exactly predict T_1 and T_2 relaxation times for a specific nanoparticle and the specific magnetic field.

The project is focused on both experimental and theoretical studies of nuclear relaxation processes in solutions of several core-shell nanoparticles with different core sizes and shell thicknesses. The major aim of the project is to develop a method that will allow to design the most efficient core-sell NPs (considering their core and shell size) at various magnetic fields, thus suitable as future contrast agents for clinical and pre-clinical MRI.

To accomplish this goal we will develop a theory of relaxivity in the presence of the core/shell nanoparticles. We anticipate the results of the project will enable to predict relaxivities of core/shell NPs at any magnetic field hence to obtain optimum MRI contrast with minimal concentrations. Furthermore, the results will allow to better understand the mechanisms of molecular interactions in complex systems, that remains the major theoretical challenge.

Our project will fill these important gaps in knowledge and will allow production of much more efficient contrast agents for clinical and preclinical MRI studies.