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Beta-detected NMR: from nuclear structure to chemistry and biology

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Beta-NMR, in which the resonances are observed as changes in beta-decay anisotropy, is over 10 orders of magnitude more sensitive than conventional Nuclear Magnetic Resonance. The method has been used widely in nuclear physics and condensed matter, but not yet in soft matter. In the former it allows determining precisely the electromagnetic moments of exotic nuclei, thus providing information on their single-particle and collective properties, while in the latter it allows looking at the local properties of different host materials.
On the other hand, in chemistry and biochemistry classical NMR is currently the most versatile and powerful spectroscopic technique for characterization of molecular structure and dynamics in solution. However, the low sensitivity leads to relatively large amounts of sample, which poses constraints on the systems that may be explored. In addition, not all elements are easily accessible, as the most abundant isotopes display no or poor response. This is where ultra-sensitivity of beta-NMR can be of value.
Our project aims at applying beta-NMR for the 1st time to soft-matter biological samples, using the newly commissioned laser spin-polarization beamline at CERN-ISOLDE. We use optical pumping with lasers to polarize isotopes of different metallic elements. The anisotropic emission of beta radiation is them used to detect NMR response, leading to the above-mentioned 10 orders of magnitude increase in sensitivity.
The scientific goal is to investigate the interaction of essential metal ions, which are otherwise difficult to address, such as Na(I), K(I), Mg(II), Cu(I), and Zn(II), with nucleic acids and proteins. In 2016 we designed, built, and commissioned the experimental setup, in 2017 we recorded the first liquid-NMR spectra, and in 2018 we have performed the first studies of the interaction of DNA G-quadruplex structures with Na(I) ions that are crucial for the structures'formation, stability, and polymorphism.
My presentation will cover the principles of beta-NMR and will compare it to conventional NMR. I will describe the experimental setup and the challenges when applying it to liquid samples, will report on the first biological results, and will mention the future plans.

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