PhD position in accelerator physics

AI for cryogenics and RF of superconducting accelerators

SPIRAL2 is one of its kind heavy ions accelerator located in Caen-France. Its heart, a superconducting linear accelerator, relies on 26 superconducting resonating cavities, cooled down to 4.2 Kelvin and operated at 88 MHz. SPIRAL2 faces specific challenges ranging from high dynamics of thermal loads, drastic level and pressure control of the superconducting cavities Helium bath, long distribution lines, vacuum pressure degradation, field emissions, cavities quenches and detuning among other ponderomotive effects. All these effects are completely different and might seem uncorrelated at first sight but they could all be linked either to the process-control or to one or several related sub-systems by some elaborated relations. Moreover, these correlations may depend on the beam parameters. When optimizing the beam from the Machine Learning and Artificial Intelligence perspective, the usual approach uses a model of the accelerator that relies on particle tracking codes. The twin model is then upgraded with hyper parameter tuning based on different diagnostics (beam, vacuum, RF, …). While this is a promising approach, it suffers from a high complexity and requires important computing resources. In this project, we propose a different yet complementary approach. It relies on utilities and sub-system level modelling, control and diagnostics. Two main sub-systems are considered: Cryogenics and Radio-Frequency. Cryogenics for superconducting accelerators has been, for some time now, mistakenly considered as a simple process utility. Yet this sub-system proved to be more complex than imagined with control parameters that heavily depend on the RF system control and, to a lower extent, on the beam configuration. In 2009, a joint R&D program between GANIL and CEA has led to the development of a thermodynamic model of the SPIRAL2 LINAC. The resulting model-based control allowed to optimize the cryogenic operation of SPIRAL2 while opening a new gateway into Machine Learning approaches for dynamic operation and intelligent fault detection through virtual sensors. However, RF and cryogenics are heavily interlaced and the models need to be completed with their RF counterpart.

The present PhD program is a continuity of the previous developments. It has two complementary phases. The first bridges previous thermodynamic models with RF modeling of the superconducting cavities. The second is the development of a fault detection framework matched to the use of classification learner algorithms such as decision trees, support vector machine (SVM), logistic regression and nearest neighbors. Offline physics-informed supervised learning is also considered for hyper parameter tuning with the use of GPU facilities at the CNRS calculation platform CCIN2P3 Lyon.

The benefits of the proposed developments are many. They span from increasing beam availability and accelerator reliability to cost saving thanks to predictive maintenance and monitoring slow performances deviations such as degradation of cavity quality factors.

<u>Expected skills:</u>
Applied physics, scientific computing, machine learning, radio-frequency, thermodynamics

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