Master Thesis proposal :

Study of the decay $B_s \to \tau^+\tau^-$ at the high-luminosity Z factory FCC-ee

Supervisor : Stéphane Monteil [@ monteil at in2p3.fr]

The Standard Model of Particle Physics (SM) describes the elementary physics interactions and has passed many experimental tests among which those realised at particle colliders are of special importance. A prominent example of colliders is the Large Hadron Collider (LHC) at CERN, used to discover in particular a narrow scalar particle of 125 GeV mass, consistent so far with the fundamental scalar boson of the SM. Although the SM well describes interactions up to O(100 GeV) energy scale, it has several shortcomings. The next energy scale of new physics that could mitigate these shortcomings is however unknown. Pushing the limits forward, the future circular collider (FCC) with its colliding electron and positron beams is expected to tighten constraints on beyond SM (BSM) theories.

The helicity-suppressed leptonic decay $B_s \to \tau^+\tau^-$ is of particular interest in this quest. It proceeds solely in the SM via loop amplitudes featuring the heaviest SM particles and constitutes therefore an appealing laboratory to capture couplings in the loop to potential new heavy particles. Furthermore, this transition, unobserved to date, connects fermions from the third generations (beauty quark and τ lepton) and provides thus information about the electroweak symmetry breaking and hence about the mass matrix of the elementary particles. To illustrate this physics reach, the companion mode $B_s \to \mu^+\mu^-$ was discovered by the LHCb experiment a decade ago and its measured branching fraction value has cornered a number of BSM scenarii.

The Master thesis internship proposed under these lines will first consist in studying the constraints that this specific decay mode can place on various BSM constructions. The second phase of the internship will be dedicated to the design of possible methods to fully reconstruct the decay even in the presence of undetected neutrinos. To do so, signal events must be simulated in the context of the FCC-ee collider operated at the Z-pole centre-of-mass energy. A selection to discriminate these signals from the rest of the events produced at the Z-pole will be studied and applied to simulated events to quantify the sensitivity of the search for this decay.

Basic knowledge in the field of particle physics is required as well as basics in programming languages like C++ and/or python.

Keywords : FCC, ElectroWeak Standard Model, rare decays of heavy-flavoured particles, kinematic and topological reconstruction.