Theory input to the ESPP update (draft, 18.1.25)

Theoretical particle physics provides **possible solutions to big questions** that the Standard Model of particle physics still leaves open, through models and concepts that go beyond our current experimentally tested knowledge.

Theory also **gives guidance** for searches to be carried out at a collider exploring the next energy or intensity frontier and for the **interpretation** of the measurements. This includes a large spectrum, ranging from model building to generic parametrisations of new physics effects through Effective Field Theories. Even completely agnostic anomaly searches (for example based on machine learning) will need substantial theory input for their interpretation.
For the identification and inference of **indirect effects of new particles** a concerted theory effort is particularly important.

The anticipated experimental precision at the next high energy collider needs to be matched by highly precise theory predictions. **Precision calculations** to reduce the perturbative uncertainties and an excellent control of non-perturbative uncertainties are therefore an essential part of the activities of the theory community. Electroweak corrections leveraged to a precision level that requires substantial conceptual and computational developments will be particularly important at future lepton colliders.

Simulation tools (Monte Carlo programs) with high efficiency and quantifiable uncertainties, based on first principles given by quantum field theory and well controlled non-perturbative parameters, are vital to fully exploit experimental results.

Calculations of such unprecedented precision are very challenging and **only feasible if supported sufficiently by corresponding resources**.
A diverse program to achieve higher precision in the theoretical predictions, going way beyond just increasing the loop order, is essential for the success of a future collider program.

The German theory community has expertise in all aspects of such a theory program, ranging from mathematical aspects of scattering amplitudes and model building to phenomenological predictions and event generators.

The broad range of activities in theoretical particle physics, from formal to phenomenological aspects, fosters **interdisciplinary research**, creating synergies with cosmology, astroparticle physics, nuclear physics, computer science and mathematics. The close **collaboration** between the **experimental and theoretical communities** that has always been supported by CERN should be invigorated.

Importance of outreach: Striving for a deeper understanding of our universe is deeply rooted in the human mind, and a facility reaching out to uncharted territory that cannot be explored by other means will inspire young researchers and fascinate the public.