

Future Circular Collider: Physics & Phenomenology



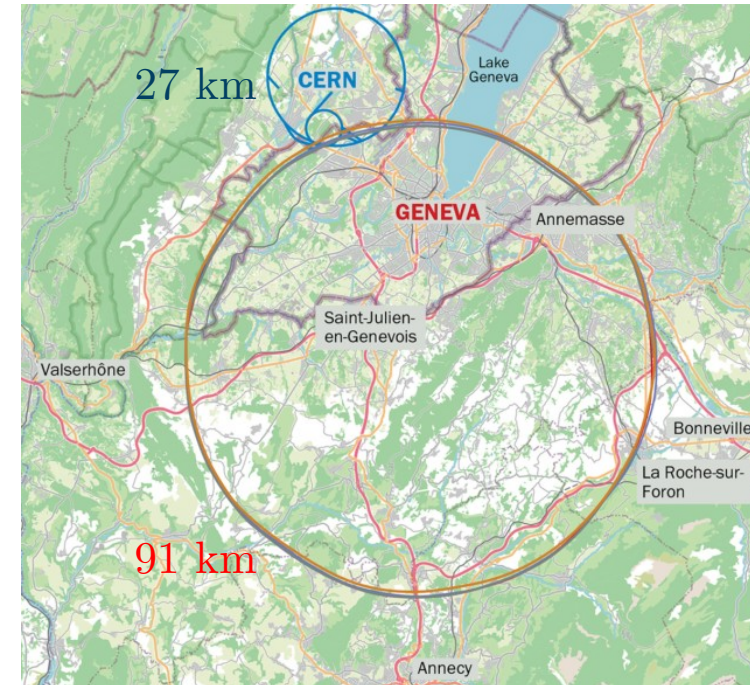
Who I am:

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- The potentially largest collider ever built (91 km ring)!
- Unprecedented precision in e^+e^- phase (**FCC-ee**) at electroweak scale!
- Push energy frontier to the 100 TeV level (**FCC-hh**) later on!
- Incredible potential to probe (new) physics well above colliding energies!



Future Circular Collider (FCC)

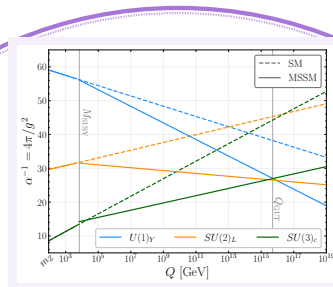
The **Future Circular Collider (FCC)** is a proposed CERN facility designed to **push the precision and energy frontiers** of particle physics. Its first stage, FCC-ee, will collide electrons and positrons in a ring with a circumference of approximately 91 km. The FCC-ee program would also provide the foundation for a **possible future hadron collider, FCC-hh**, extending the search for new particles to substantially higher collision energies.

Why do we need a new collider?

- ▶ We do NOT know the **structure of matter/spacetime** at distance shorter than 10^{-20} m.
- ▶ There are many **theoretical puzzles/limitations to the SM** (naturalness of the Higgs mass, the structure of the flavour sector, inclusion of gravity...)
- ▶ The Standard Model has some seemingly "accidental" aspects (e.g. B and L number conservation) and "unusual" features (e.g. critical EW-scale).
- ▶ What we will learn and discover might become the **drivers of economy in 50 or 100 years**, also on the technical side!

Precision physics as a discovery tool

- ▶ will become a **Higgs and electroweak factory**, enabling precise measurements of the Higgs boson, the Z' boson and other Standard Model (SM) parameters
- ▶ in the Higgs sector: **precision on these couplings up to 0.1%**, giving an indirect sensitivity from up to scales of 100 TeV
- ▶ **multiple centre-of-mass energies** and production modes provide complementary **probes of SM interactions and parameters** (e.g. m_W , CKM-elements...).
- ▶ Dramatically improve **sensitivity to new interactions through precision** measurements and fits to couplings in effective field theories.
- ▶ **Search for new physics both directly**, through particle production, and **indirectly**, through deviations from SM predictions.



Supersymmetry and Grand Unified theories

One exploration we worked on is the testing of Grand unified theories at FCC-ee. For that we will take use of **supersymmetric theories (eg. (C)MSSM)**, which improves the **unification of the couplings** of the standard model gauge group $SU(3)_C \times SU(2)_L \times U(1)_Y$.

The value of the couplings α_i is changing, depending on the scale at which the coupling is evaluated. The change in scale can be calculated by the **renormalization group equations (RGE's)**. At every scale the theory is changing (**here at M_{SUSY} and Q_{GUT}**), **threshold corrections** need to be included as well, resulting from the mass splitting of the involved particles. A long motivated theory at high energies, so called Grand Unified Theories, would unify the three couplings to one value α_5 . Threshold corrections at 1-loop at the Q_{GUT} for $SU(5)$:

$$\begin{aligned}\alpha_1^{-1}(Q) - \alpha_5^{-1}(Q) &= -\frac{1}{4\pi} \left[2 \log \frac{Q^2}{M_H^2} + 10 \log \frac{Q^2}{M_K^2} \right], \\ \alpha_2^{-1}(Q) - \alpha_5^{-1}(Q) &= -\frac{1}{4\pi} \left[-2 \log \frac{Q^2}{M_H^2} + 6 \log \frac{Q^2}{M_K^2} \right], \\ \alpha_3^{-1}(Q) - \alpha_5^{-1}(Q) &= -\frac{1}{4\pi} \left[-\log \frac{Q^2}{M_H^2} + 4 \log \frac{Q^2}{M_K^2} - 3 \log \frac{Q^2}{M_L^2} \right],\end{aligned}$$

At FCC-ee the couplings get **measured at low energies**, mostly around the Z-boson mass $m_Z \sim 91$ GeV, improving the **precision on the α_i 's by a factor of ~ 10** . This will also reduce the uncertainties $\Delta\alpha_i$ in the evolved couplings, at the high scale of unification, showing a need for higher loop calculations in SUSY and at the GUT threshold (up to 4- and 2-loop respectively).

A special focus should be on the threshold corrections, which can greatly **influence the resulting conclusions going from 3- to 2-loop in SUSY**.

Thanks and
come check
the poster!

