Why we need SM measurements?

- Two obvious reasons:
  - **SM processes are backgrounds for new physics searches**
    - If you do BSM you need to know your SM processes first
  - **Measurements can be THE way to find new physics**
    - Considering the lack of new particles or significant new effects
    - We may find them in **deviations with respect to the predictions**

- There is also a third one:
  - **The Higgs boson is a SM particle** (or so it seems, sigh!)
    - It is still very new, there is much to learn from the Higgs sector

- **In the next years we have the potential to stress-test the SM like never before**
  - **A comprehensive program of measurements/theory developments is needed**

Main strategic objectives

- **Precision**
  - both in the measurements and in the theoretical predictions
- **To probe extreme corners of the phase space**
  - inclusive and (multi-)differential
  - exploring rare production and decay modes
- **To integrate measurements and searches**

Implications

- On the **experimental side**:
  - higher luminosities (at the LHC and elsewhere)
  - higher collision energies --push the energy frontier
  - better detectors
  - smaller systematic uncertainties

- On the **theory side**:
  - improving perturbative calculations by going to higher orders
  - including both QCD and EW corrections
  - understanding better non-perturbative effects

SM measurements shopping list

- Characterization of the **Higgs boson**
  - mass, width and couplings
  - **top-Higgs Yukawa coupling and Higgs self-coupling** --high priority
- Measurements on other heavy particles
  - **important for BSM searches**
  - top quarks, W/Z bosons
    - top quark and W boson masses – tests of SM consistency via electroweak fits
- Testing the SM ↔ improving our understanding of the SM as such
  - pinning down other relevant SM parameters
  - QCD
  - minimum bias
- In all cases
  - **multi-differential measurements** --interface theory predictions, modeling, and the data
    - constrain important SM quantities and BSM models
  - Exploring extreme corners of phase space
- Study of high pileup environments (and how to adapt our hardware and software to them)
- Precise estimation of the luminosity
  - associated uncertainty is already a limiting factor for some of our precision measurements

SM theory shopping list

- **Increased experimental precision must be matched with advances in the precision of theoretical calculations**

- QCD NLO predictions state-of-the-art today
  - for arbitrary processes embedded in detailed simulations of full events
  - some special observables calculated to NNLO or even N^3LO
- Increased precision requires:
  - going to even **higher orders** for selected processes
  - a general scheme of **combining EW and QCD corrections with full event simulation**, taking care to also improve the treatment of resummation and non-perturbative effects, to understand better the accuracy of the predictions.
  - better models for minimum-bias events is important to understand better the pile-up in high luminosity environments

- Other:
  - Tools for experiment/theory comparisons
  - Low energy high precision phenomenology
  - Forward physics

Experimental facilities

- As in any other topic, different objectives can be reached depending on the experimental facilities available and the advance of the theory
  - **Precision measurement of the Higgs self-coupling → HL-LHC unlikely to be sufficient**
    - HE-LHC, FCC, or at a linear collider with a sufficient energy
- To go below certain thresholds in e.g. the systematic uncertainty associated to top quark measurements
  - **a linear collider that can access the top quark**
  - a more precise estimation of the luminosity at the LHC and beyond and improved modelling
- Precise QCD measurements could be done at the **HL-LHC** using partial data reconstruction techniques in low pileup datasets
  - **HE-LHC would be needed in order to measure QCD at the highest energy scales**
- SM / BSM searches can be performed in pile-up collisions that so far we have been throwing away
  - HGTD in a HL-LHC context could help and also a precise luminosity estimation will be needed.