4th of March 2026 **Quiz number 2**

Phenomenology of Physics Beyond the Standard Model

FS 2026

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1. Probing the Higgs boson properties at the LHC

Take as a main reference the paper from the CMS collaboration [1] published on Nature.

- Considering the Standard Model, how many of its free parameters come from the Higgs sector ? Why is it so relevant to understand such sector ?
- For the minimal SM potential for the Higgs field ($V(\phi) = -\mu(\phi^\dagger\phi) + \lambda(\phi^\dagger\phi)^2$), how are the mass, the EW vacuum expectation value and the self-interaction coupling related ? Thus, in the SM what is the only free parameter of the potential ? How was this parameter measured by the LHC experiments ?
- What is the strategy adopted by the LHC experiments to assess the strength of the Higgs boson signal in different production modes and channels ? What is the approach adopted to study the couplings of the Higgs boson ?
- Looking at the plot in Figure 1, can you guess why some of the signal strengths are measured more precisely than others ?
- Looking at Figure 2, why can the di-Higgs production be considered a search more than a measurement ? Why is the cross-section for $pp \to HH$ so low? To what information does this measurement give access to compared with the mass measurement ? (*Hint: Look back to the question in point 2*)

2. Proton decay and SU(5) GUT

Explain how in the $SU(5)$ Grand Unified Theory the proton decay is allowed.

- Sketch the Feynman diagram for $p \to e^+\pi^0$. Which boson can mediate this process ?
- Which classical global symmetry is assumed to be broken within this process? Which new symmetry is still valid ?
- Looking at the plot in Figure 3, what is the problem with the minimal $SU(5)$ GUT ? How naively can SUSY solve the problem ?

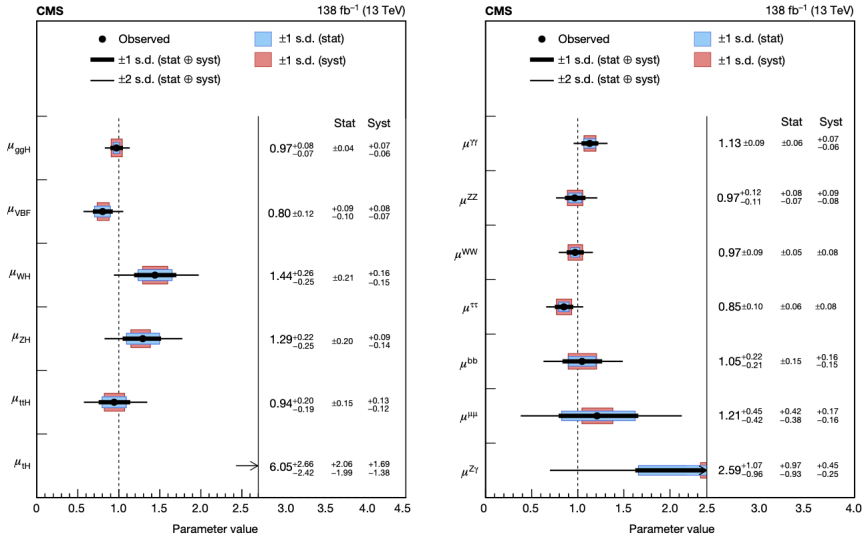


Figure 1: Overview of the measurements of the Higgs boson production and decay signal strengths [1].

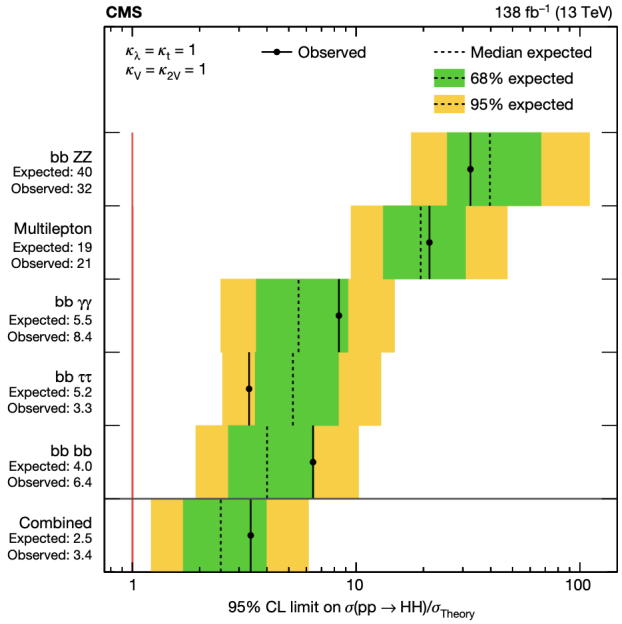


Figure 2: 95% CL upper limits on the di-Higgs production cross-section. [1]

References

[1] "A portrait of the Higgs boson by the CMS experiment ten years after the discovery". In: *Nature* 607.7917 (2022), pp. 60–68. DOI: 10.1038/s41586-022-04892-x. arXiv: 2207.00043 [hep-ex].

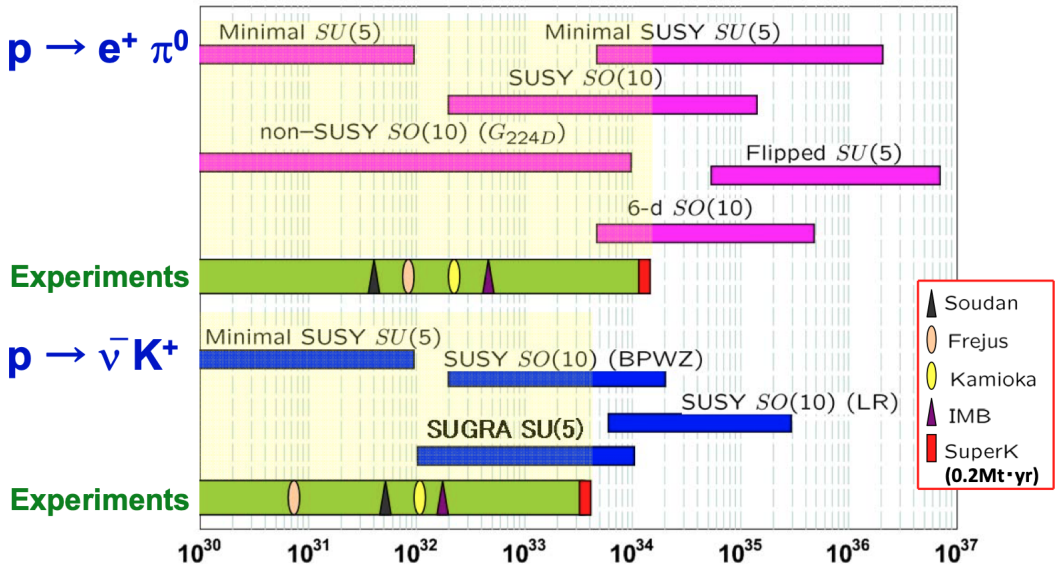


Figure 3: Overview of constraints on the proton life-time for different BSM scenarios.