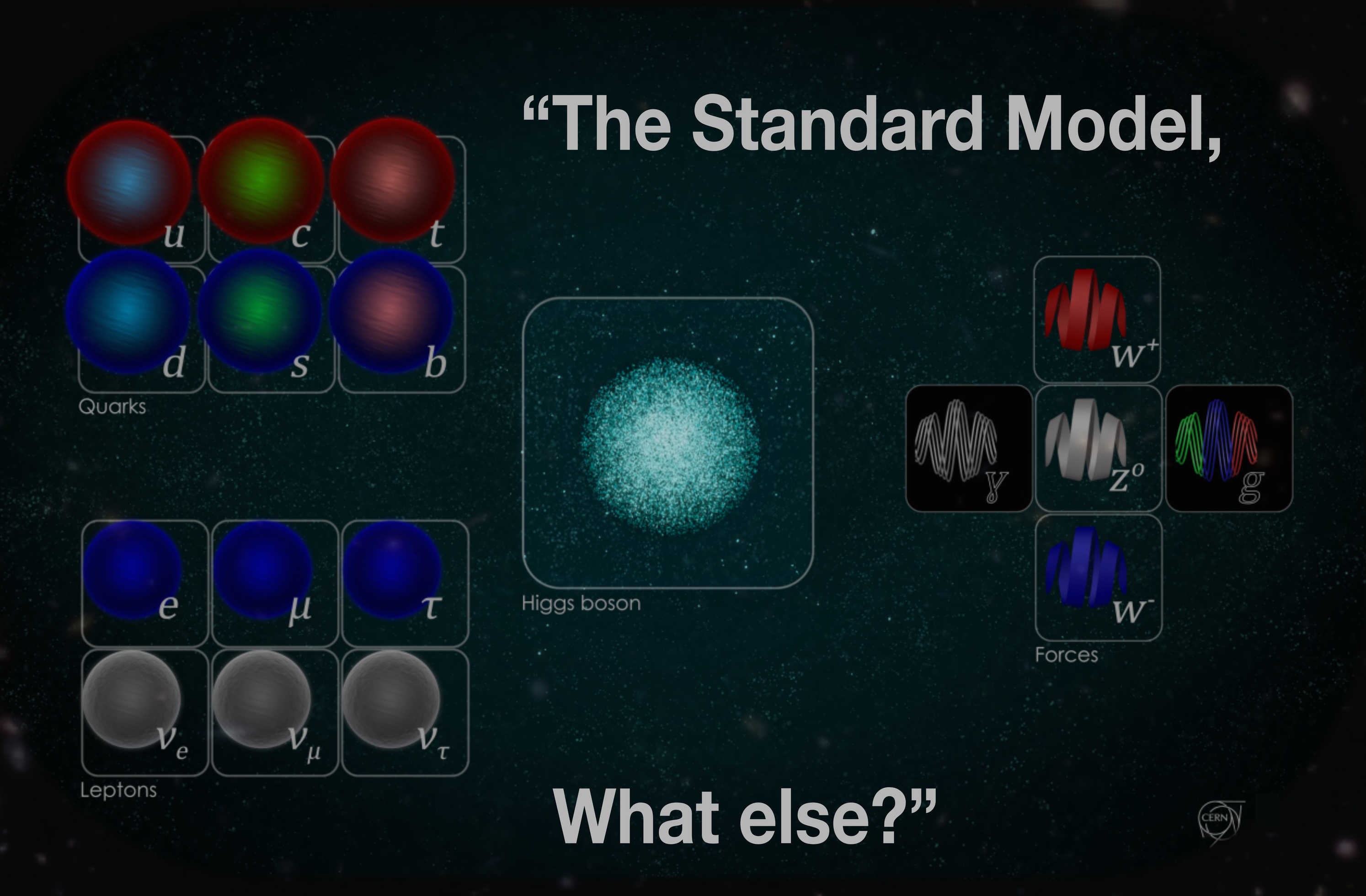
Search for H(γγ)+c production at CMS

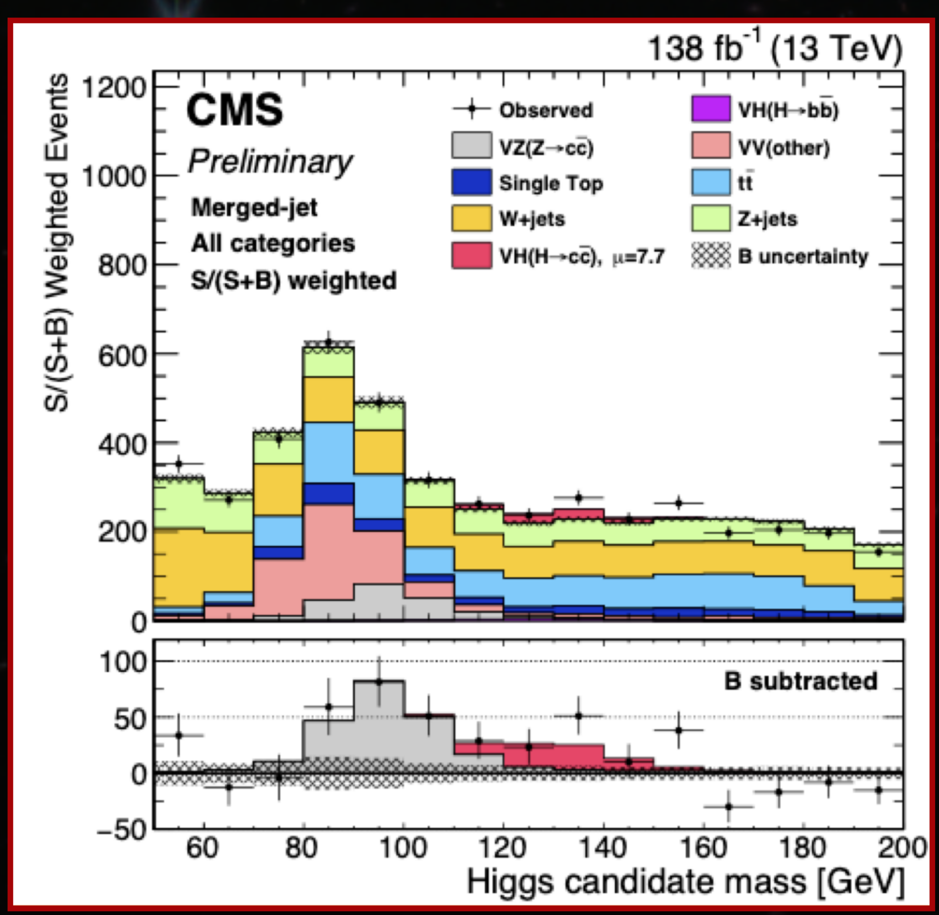
Tiziano Bevilacqua (PSI, UZH)

The Standard Model (SM) of particle Physics

Since the 1930s the efforts of particle physicists have resulted in a remarkable insight into the fundamental structure of matter:

- Everything in the universe is found to be made from a few basic building blocks, governed by four fundamental forces.
- The SM has successfully explained experimental results and precisely predicted a wide variety of phenomena.
- The Higgs boson was the last addition to the SM, theorized in 1964 it was discovered at the Large Hadron Collider in 2012.
- A few important questions remain unanswered: "**What is Dark Matter?**", "**What happened to the antimatter after the big bang?**", "**What about Gravity?**"





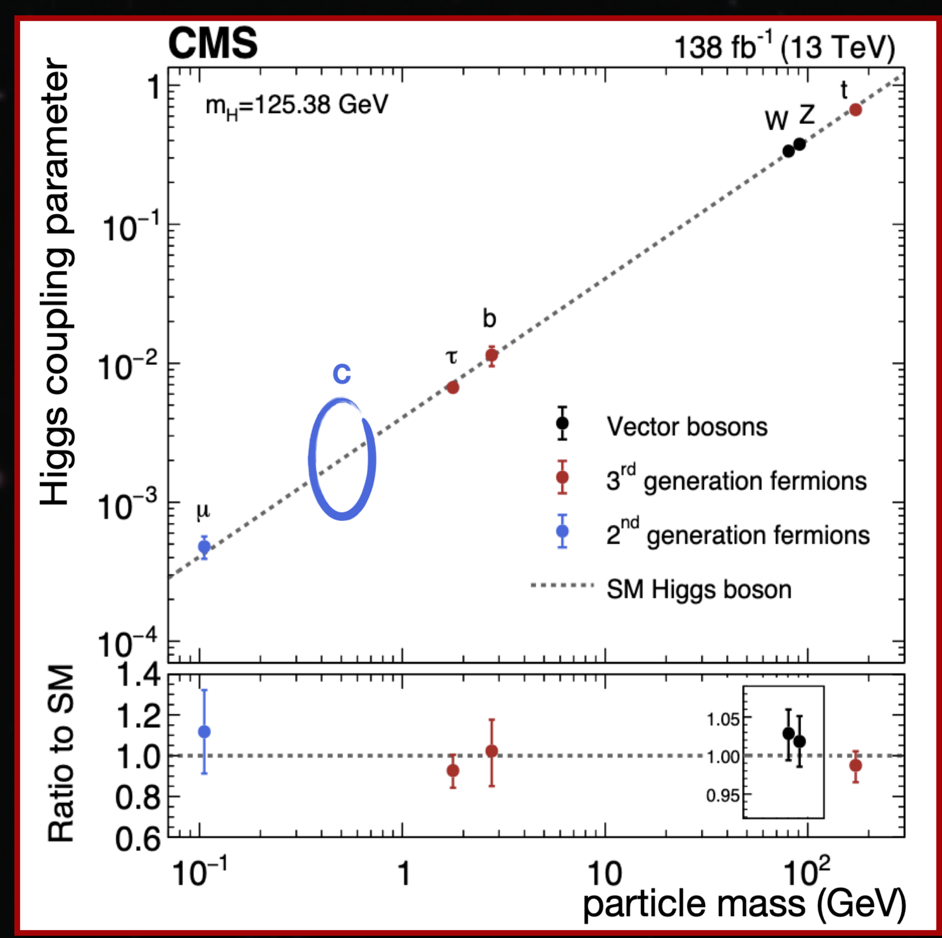
Motivation

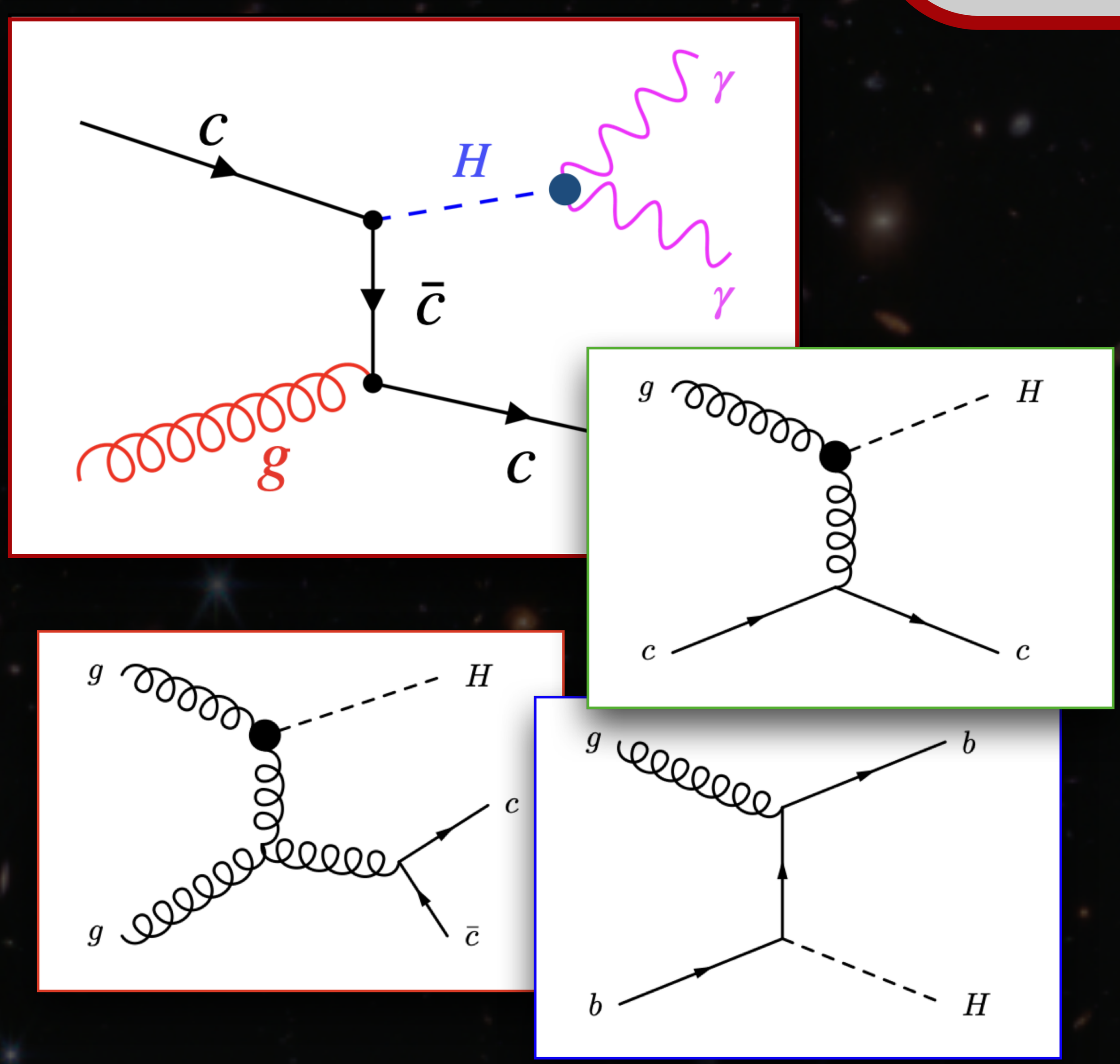
Higgs couplings to other particles are predicted by the SM and proportional to particle mass. Deviation in the measured values could hide new physics.

3rd generation couplings already measured,
2nd generation fermion couplings are one of the primary goals of CMS physics program:

$H \rightarrow \mu\mu$: 3σ evidence (CMS (2021) [1])
What about charm?

Limit on the signal strengh μ shrinked from ~8000 to 7.6 in the last few years. Most stringent limit from direct search of the $H \rightarrow c\bar{c}$ decay in the VH channel [2].





H+c associated production

Interesting channel, not yet tested experimentally. Complementary approach to other searches, theory studies predict it to reach sensitivities close to SM ($|k_c| < 3.9$) at HL-LHC [3].

Experimental advantages:

- Leading contribution requires only 1 charm to be tagged.
- All H decays are available, ability to exploit the cleanest ones ($\gamma\gamma/ZZ \rightarrow 4L$).
- Uncovered phase space, complementary to existing $H \rightarrow c\bar{c}$ searches.

But also some challenges:

- H+c final state includes several contributions that do not depend on $y_c \implies$ most of the H+c cross section not depending on the charm coupling, with reducible and irreducible bkgs.
- No existing Monte Carlo (MC) simulation that addresses the y_c induced H+c production in CMS.
- Soft c-tagging.

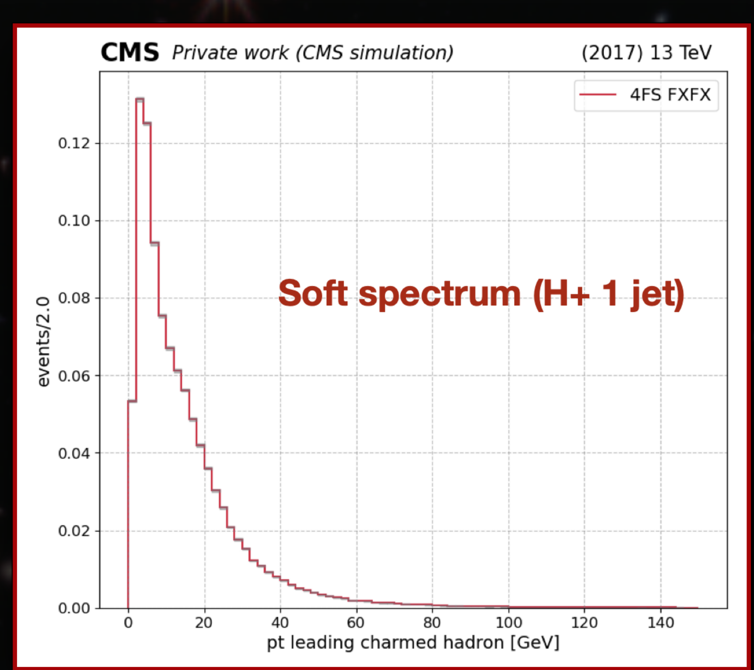
H+c simulation

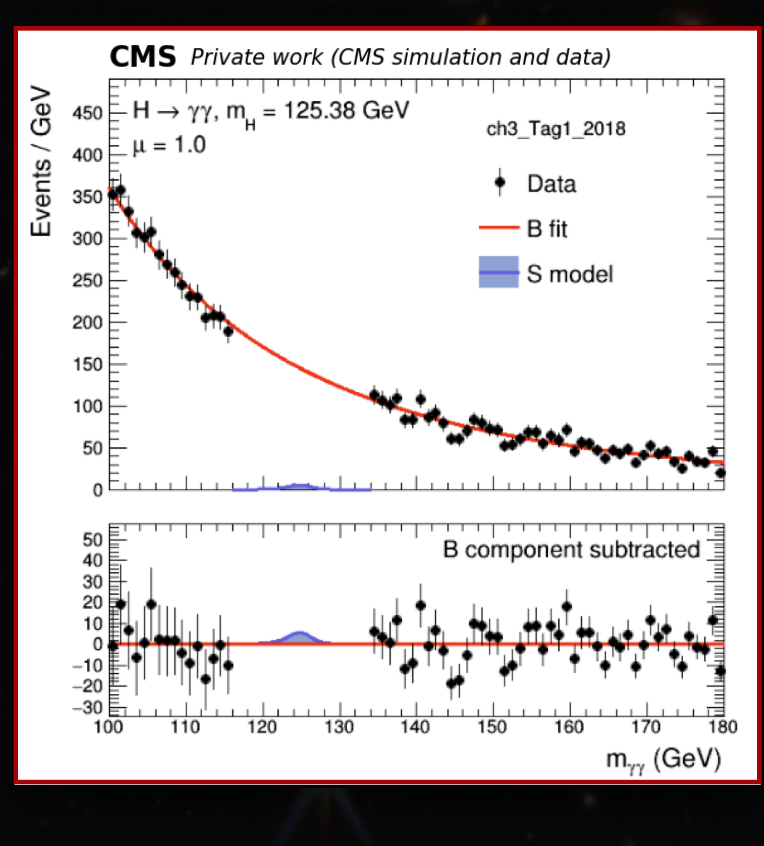
H+c production simulated with MadGraph_aMC@NLO [4].
$\sigma(hc)$ does not scale trivially with y_c : $\sigma(hc) = A + B \cdot y_c + C \cdot y_c^2$

- Biggest contribution from term not probing y_c (~250 fb).
- y_c^2 term is the most interesting (~35 fb).
- Small interference term (~-3 fb).

Generation of signal probing y_c^2 and bkg in separate MC, ignoring the interference term (O(1%)):

- Simulation done at NLO [QCD] + Pythia8 PS.
- Use of $\overline{MS}$ renormalisation scheme to include the running of coupling and mass of the c quark.
- ME calculation is performed considering massless c quarks.





H(γγ)+c analysis

Event selections requires one good diphoton candidate and at least one charmed-jet.

- Main bkgs are "standard" H production through gluon fusion and continuos non-H diphoton events (γγ or γ+fakes).
- Usual H(γγ) approach, fit the γγ mass distribution.
- The fit is performed simultaneously on 9 cat. defined according to:
  1) BDT trained to separate H+c vs ggH.
  2) BDT trained to separate H+c vs CB.

The background modelling in the analysis is done with a data driven method.

Overview

The strategy for the CMS H+c analysis is presented here, the new approach is promising and shows good complementarity with other searches. The analysis is still blinded, with an expected limit on k_c of O(20). **Stay tuned!**

University of Zürich poster session
23/24-11-23

references