Physics and Astronomy

UNIVERSITY OF Southampton

Phenomenology Lectures

Higgs

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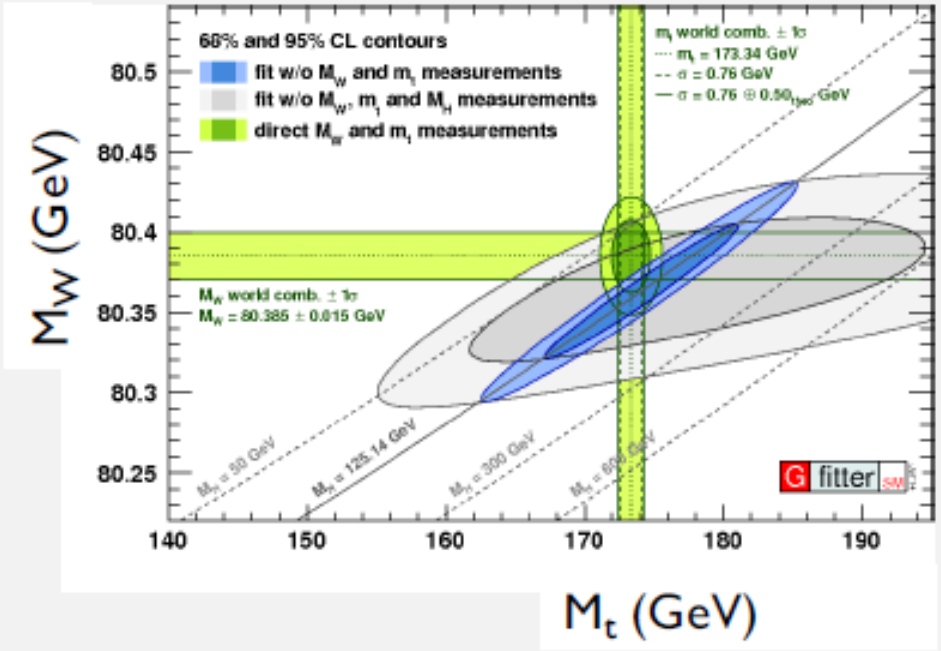
July 2020

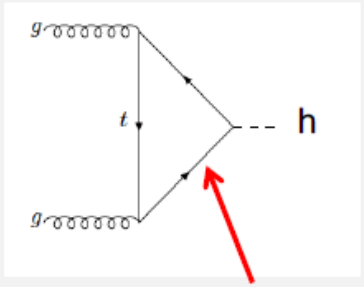
THE SM WORKS (GLOBAL FIT)



Measurements sensitive to $\ln(M_h)$ terms

Heavy Higgs excluded by precision measurements even without observation

HIGGS PRODUCTION AT A HADRON COLLIDER



Depends on new physics in loop

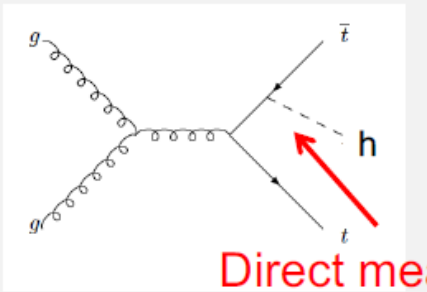
Most important processes:

$$gg \to h$$

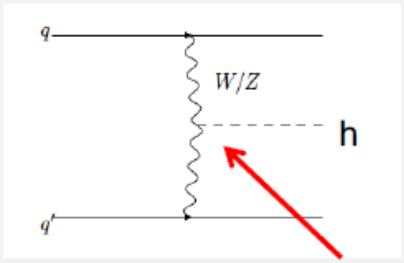
$$q\bar{q} \to q\bar{q}h$$

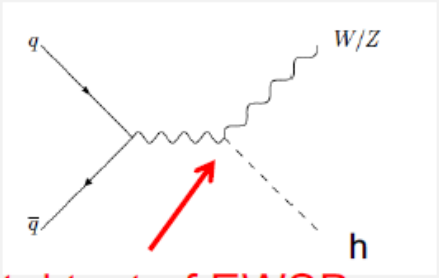
$$q\bar{q} \to q\bar{q}h$$

$$q\bar{q}, gg \to t\bar{t}h$$



Direct measurement of tth Yukawa

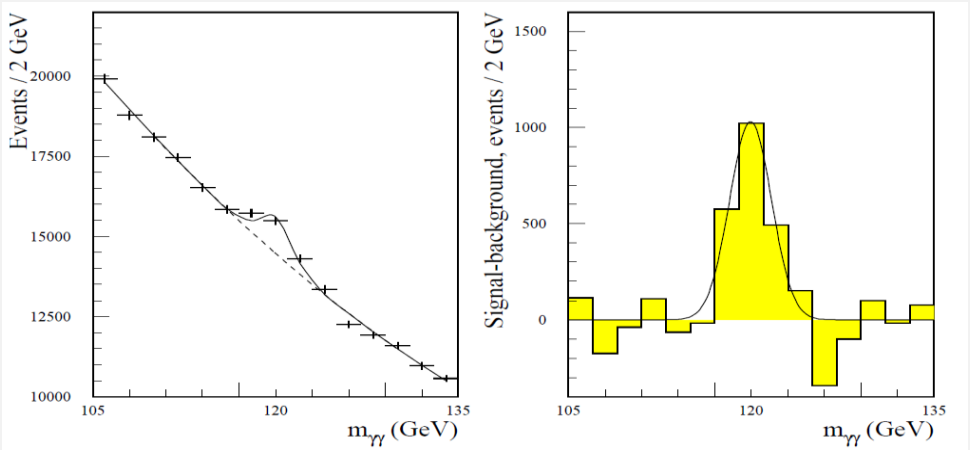


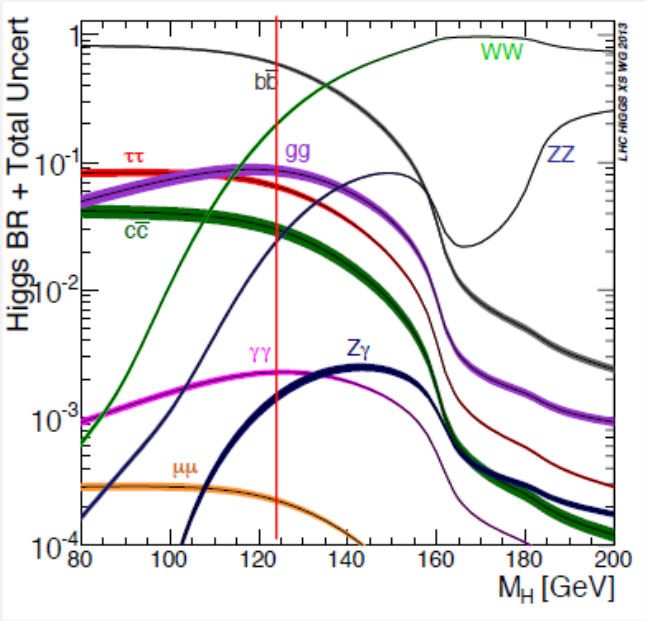


Vanishes if v=0: Fundamental test of EWSB mechanism

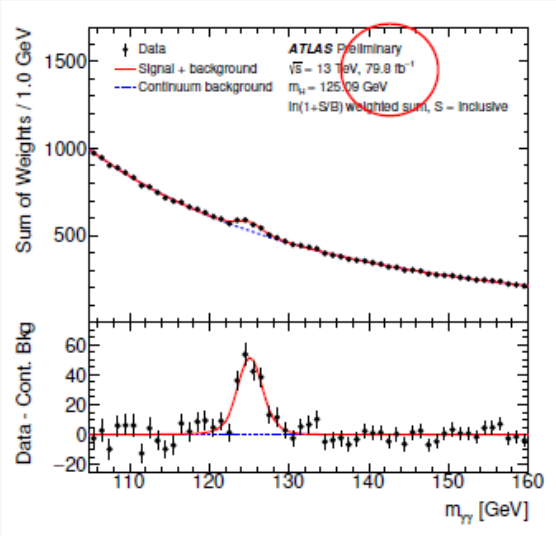
HIGGS DECAYS AND WIDTH

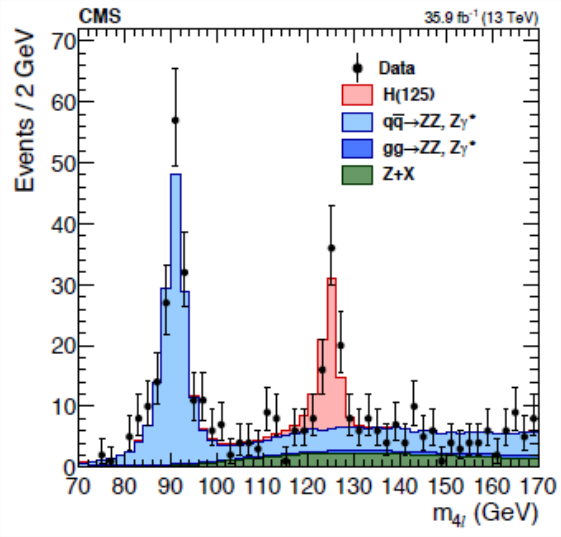
- Γ_{SM}=4 MeV << detector resolution
- Width is sensitive to light "invisible" particles





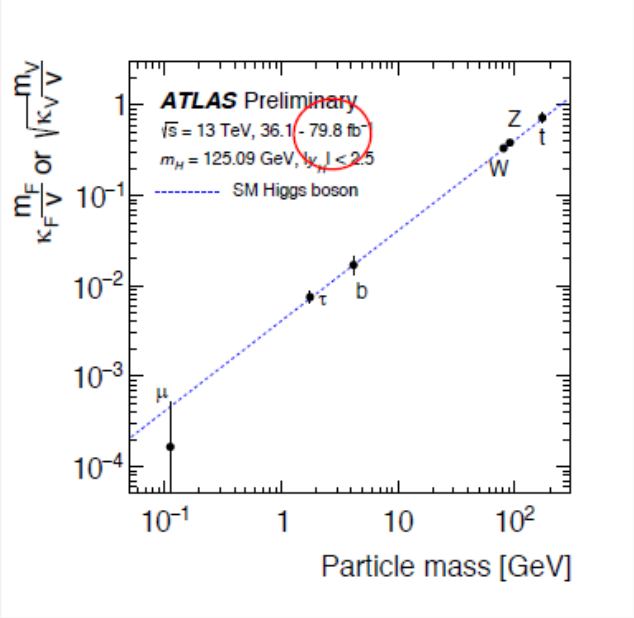
WE'VE DISCOVERED A "HIGGS-LIKE" PARTICLE

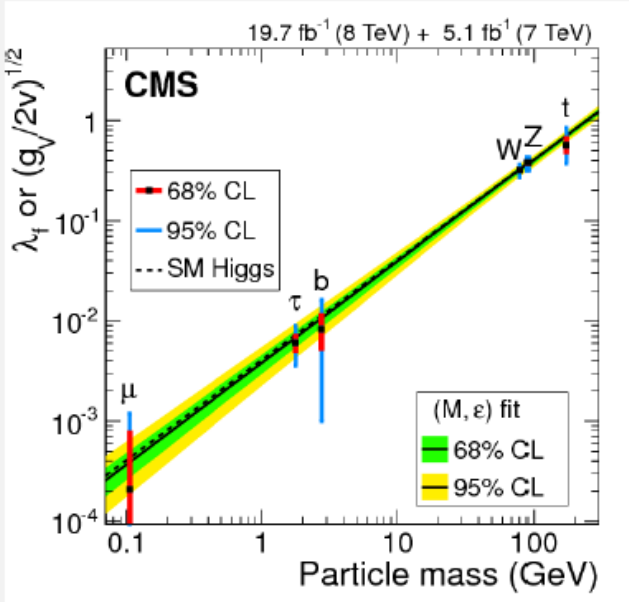




How do we prove it's the object predicted by the Standard Model, and not the low energy manifestation of some more complicated theory?

GENERICALLY, IT LOOKS LIKE SM COUPLINGS





WHAT DO WE EXPECT TO LEARN IN THE FUTURE?

PDG, 2017

H^0 $J = 0$

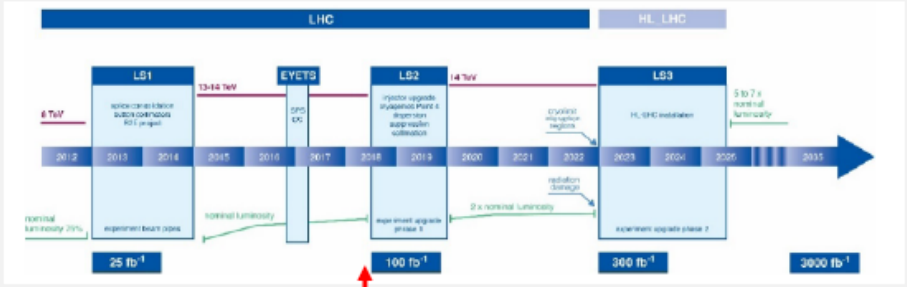
Mass $m = 125.09 \pm 0.24$ GeV
Full width $\Gamma < 0.013$ GeV, CL = 95%

H^0 Signal Strengths in Different Channels

See Listings for the latest unpublished results.

Combined Final States $= 1.10 \pm 0.11$
$WW^* = 1.08^{+0.18}_{-0.16}$
$ZZ^* = 1.29^{+0.26}_{-0.23}$
$\gamma\gamma = 1.16 \pm 0.18$
$b\bar{b} = 0.82 \pm 0.30$ (S = 1.1)
$\mu^+\mu^- = 0.1 \pm 2.5$
$\tau^+\tau^- = 1.12 \pm 0.23$
$Z\gamma < 9.5$, CL = 95%
$t\bar{t}H^0$ Production $= 2.3^{+0.7}_{-0.6}$

Normalized to SM



We are here

A good time to take stock of physics goals

If theory is incomplete, interpretations of Higgs results inaccurate

WHAT ARE THE MISSING PIECES?

- Fermion couplings to b, t, τ
- Gauge boson couplings to W/Z/g/γ
- Higgs is spin 0
- No measurements of hZγ, 2nd generation fermions, h^3, h^4 couplings….
- Higgs h^2 coupling (Mass)

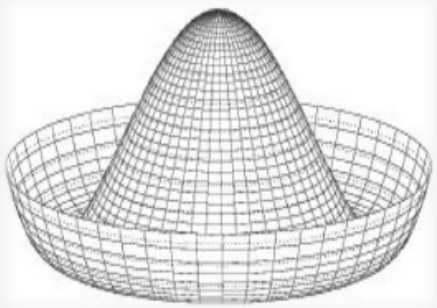
HIGGS SELF-COUPLING BIG MILESTONE

- We don't know that the Higgs comes from the scalar potential

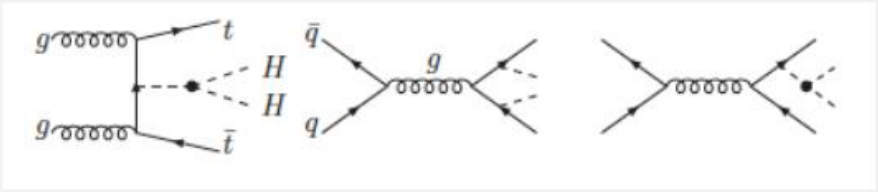
$$V = \mu^2 \phi^\dagger \phi + \lambda (\phi^\dagger \phi)^2$$
$$= \frac{M_h^2}{2} h^2 + \lambda_3 h^3 + \lambda_4 h^4$$

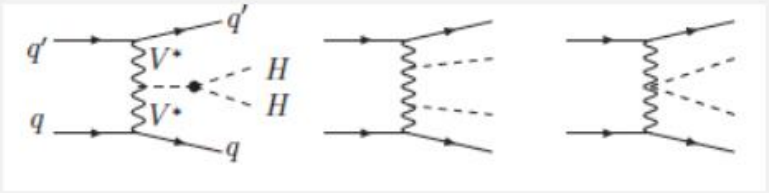
- SM is perturbative

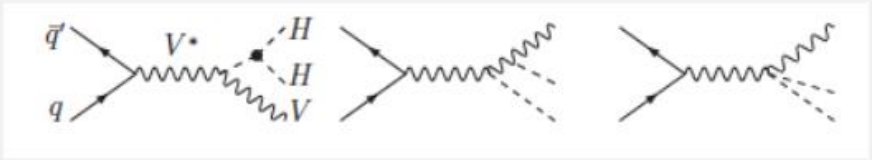
$$\lambda_3 = \frac{M_h^2}{2v} \sim .13v, \qquad \lambda_4 = \frac{M_h^2}{8v^2} = .03$$



PRODUCTION OF hh



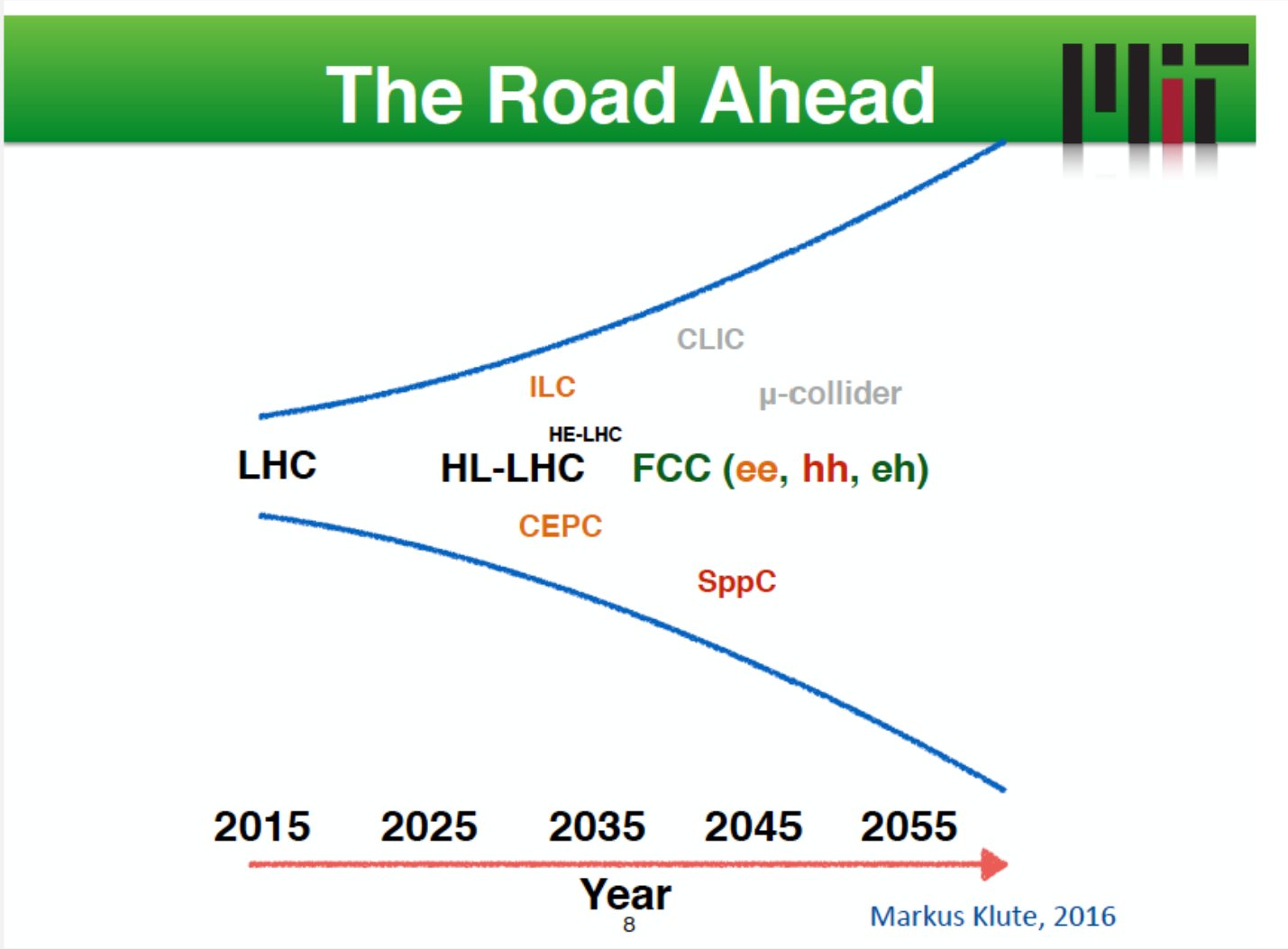




Sensitive to heavy colored particles (eg stops or top partners)

Sensitive to anomalous top-Higgs couplings

Sensitive to anomalous VVhh couplings


The Road Ahead
CLIC
ILC
μ-collider
HE-LHC
LHC
HL-LHC
FCC (ee, hh, eh)
CEPC
SppC
2015
2025
2035
2045
2055
Year
8
Markus Klute, 2016