Higgs physics: ten years after the discovery

Giulia Zanderighi

Max Planck Institute for Physics & Technische Universität München

Casa de Zafra, Granada

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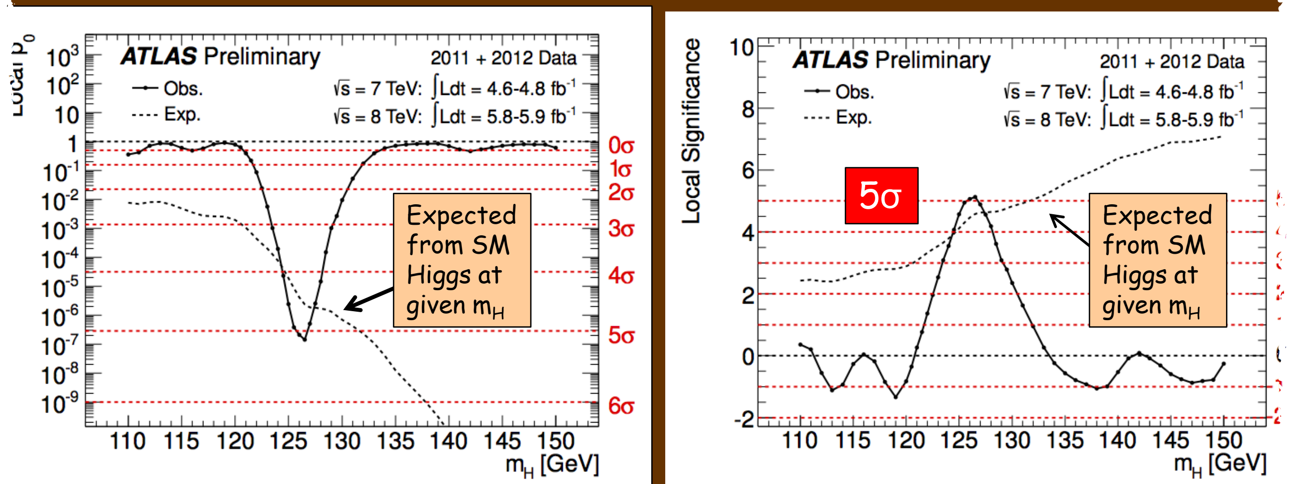
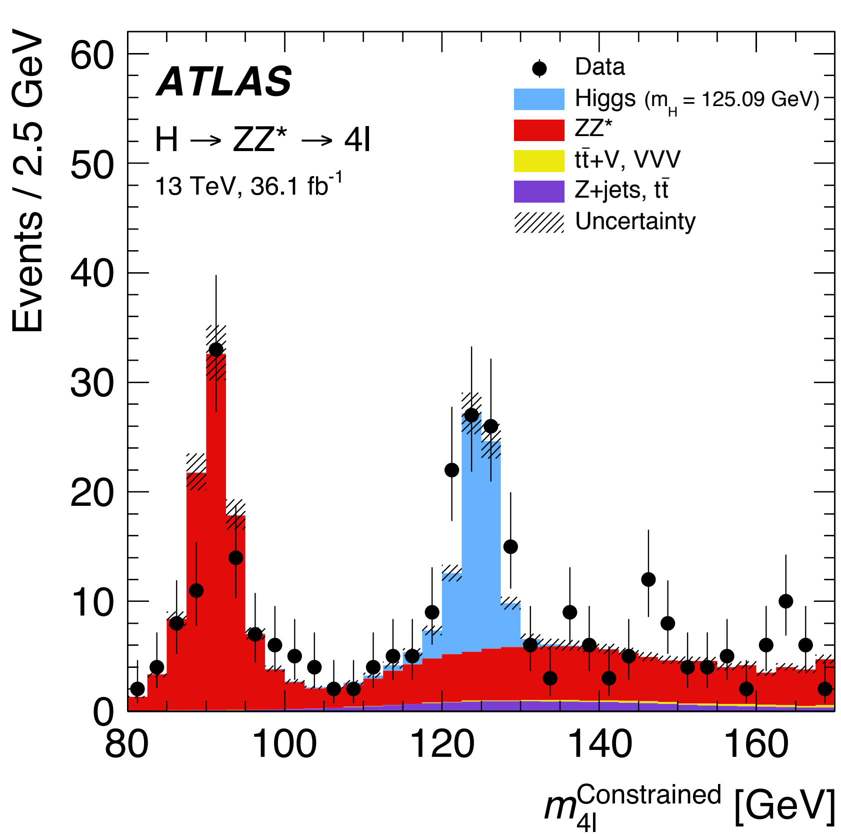
CERN, 4th July 2012

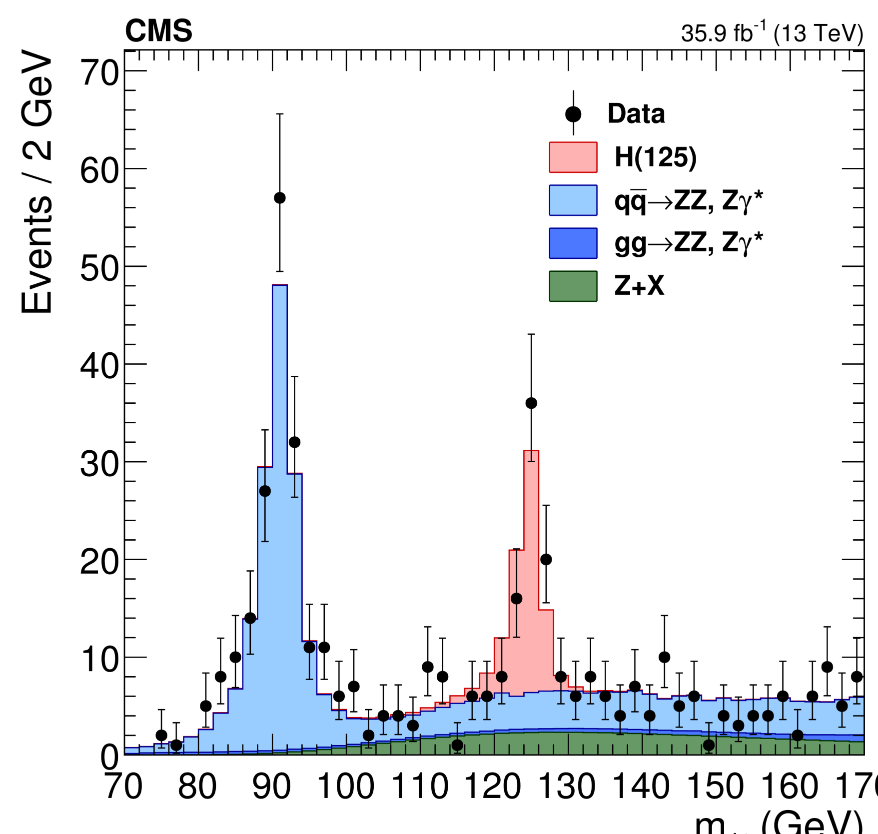
Combined results: the excess



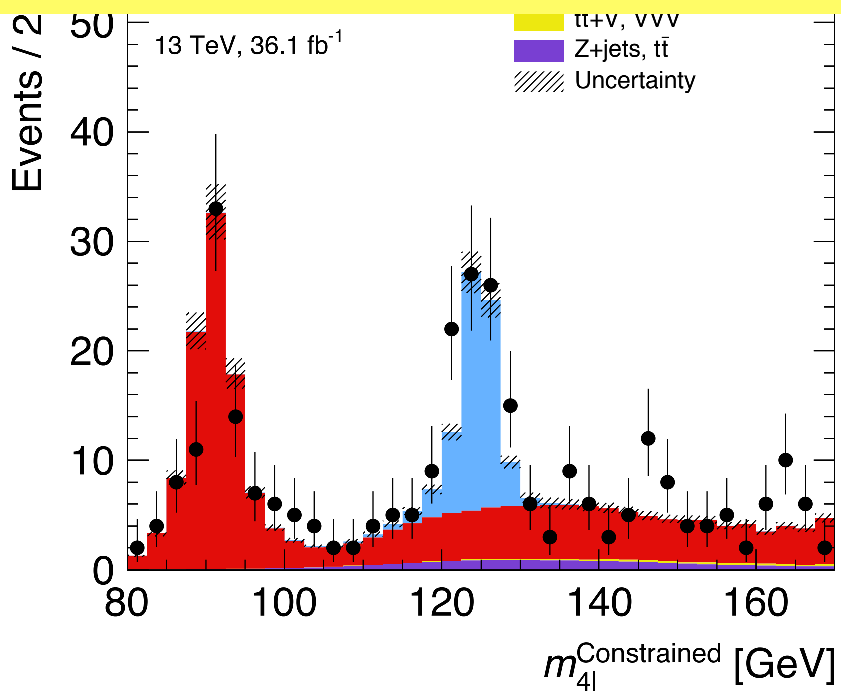
Maximum excess observed at	m_H = 126.5 GeV
Local significance (including energy-scale systematics)	5.0 σ
Probability of background up-fluctuation	3 x 10^{-7}
Expected from SM Higgs m_H=126.5	4.6 σ

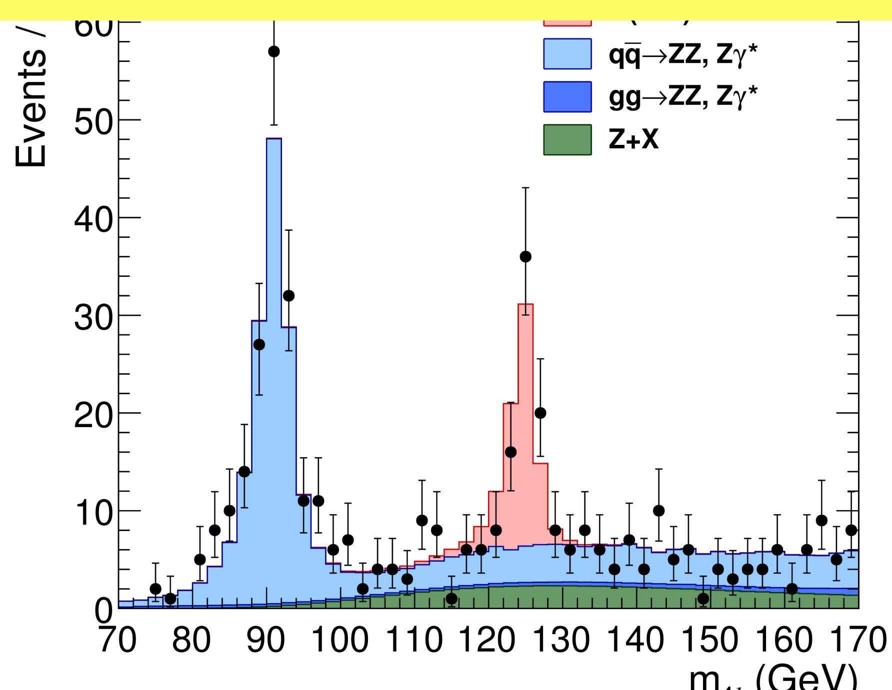

RESER
VED


ATLAS
H → ZZ* → 4l
13 TeV, 36.1 fb^{-1}
Data
Higgs (m_H = 125.09 GeV)
ZZ*
$t\bar{t}$+V, VVV
Z+jets, $t\bar{t}$
Uncertainty
Events / 2.5 GeV
$m_{4l}^{\mathrm{Constrained}}$ [GeV]
0
10
20
30
40
50
60
80
100
120
140
160


CMS
35.9 fb^{-1} (13 TeV)
Data
H(125)
$q\bar{q}$→ZZ, Zγ*
gg→ZZ, Zγ*
Z+X
Events / 2 GeV
m_{4l} (GeV)
0
10
20
30
40
50
60
70
70
80
90
100
110
120
130
140
150
160
170

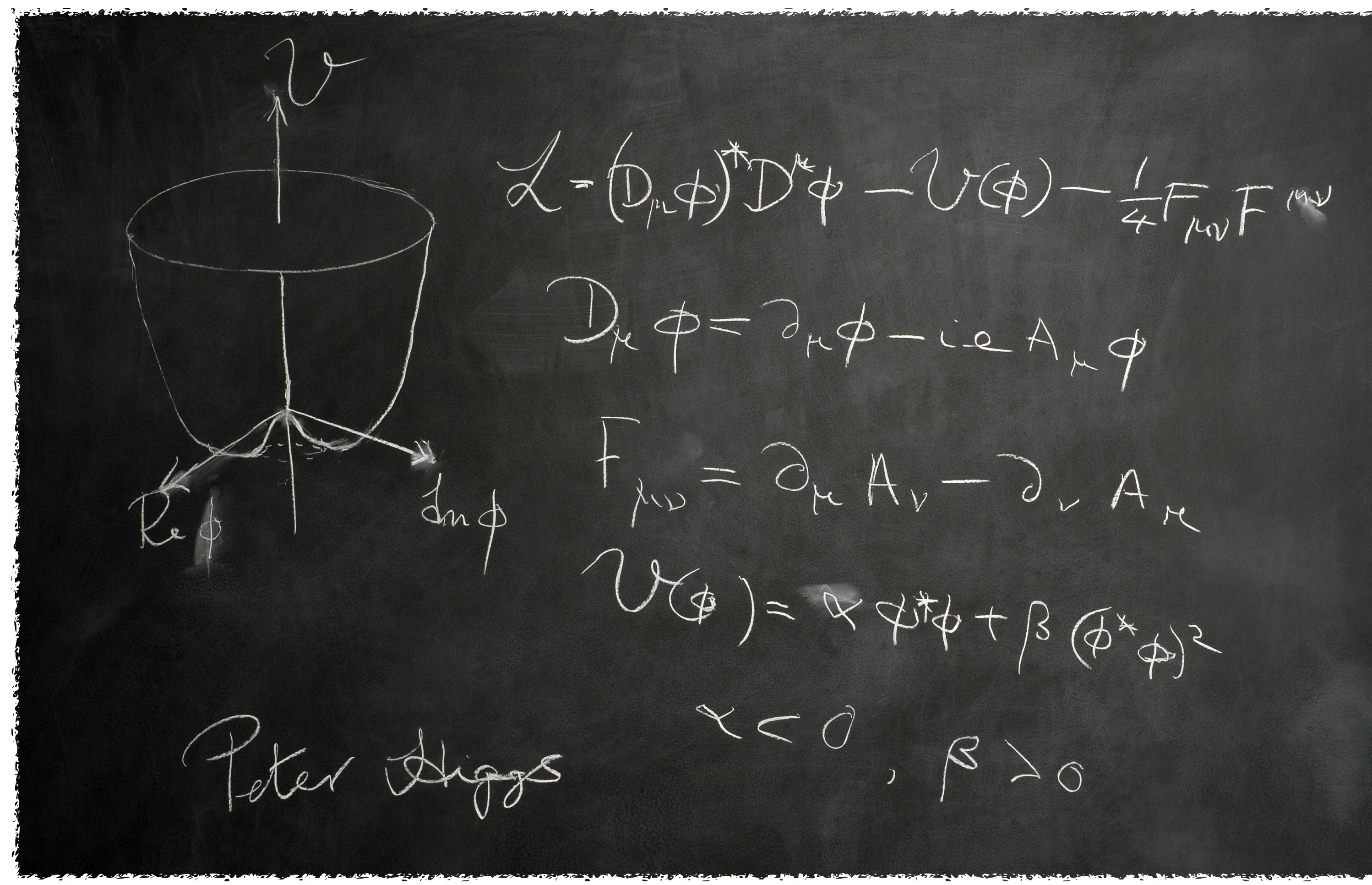
The beginning of a new era!



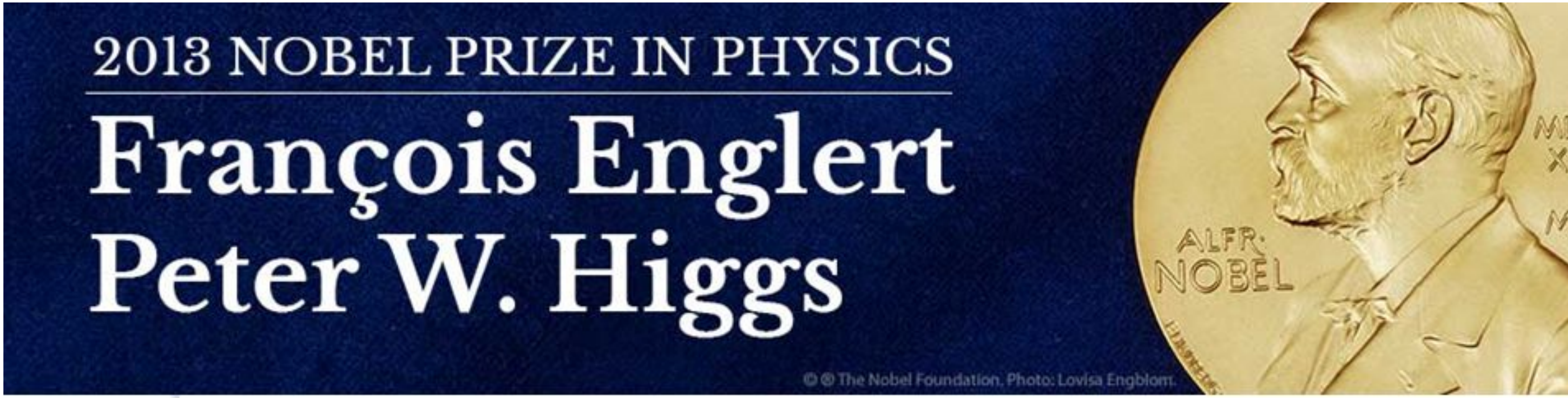


The SM Lagrangian

The discovery was a remarkable confirmation of the simplest and elegant idea postulated in the sixties, i.e. that a Higgs field, with a non-zero vacuum expectation, is responsible for the generation of masses of Standard Model particles in a consistent way



Higgs Phys. Lett. 12 (1964) 132-133
Englert and Brout Phys. Rev. Lett. 13 (1964) 321-323



8 October 2013

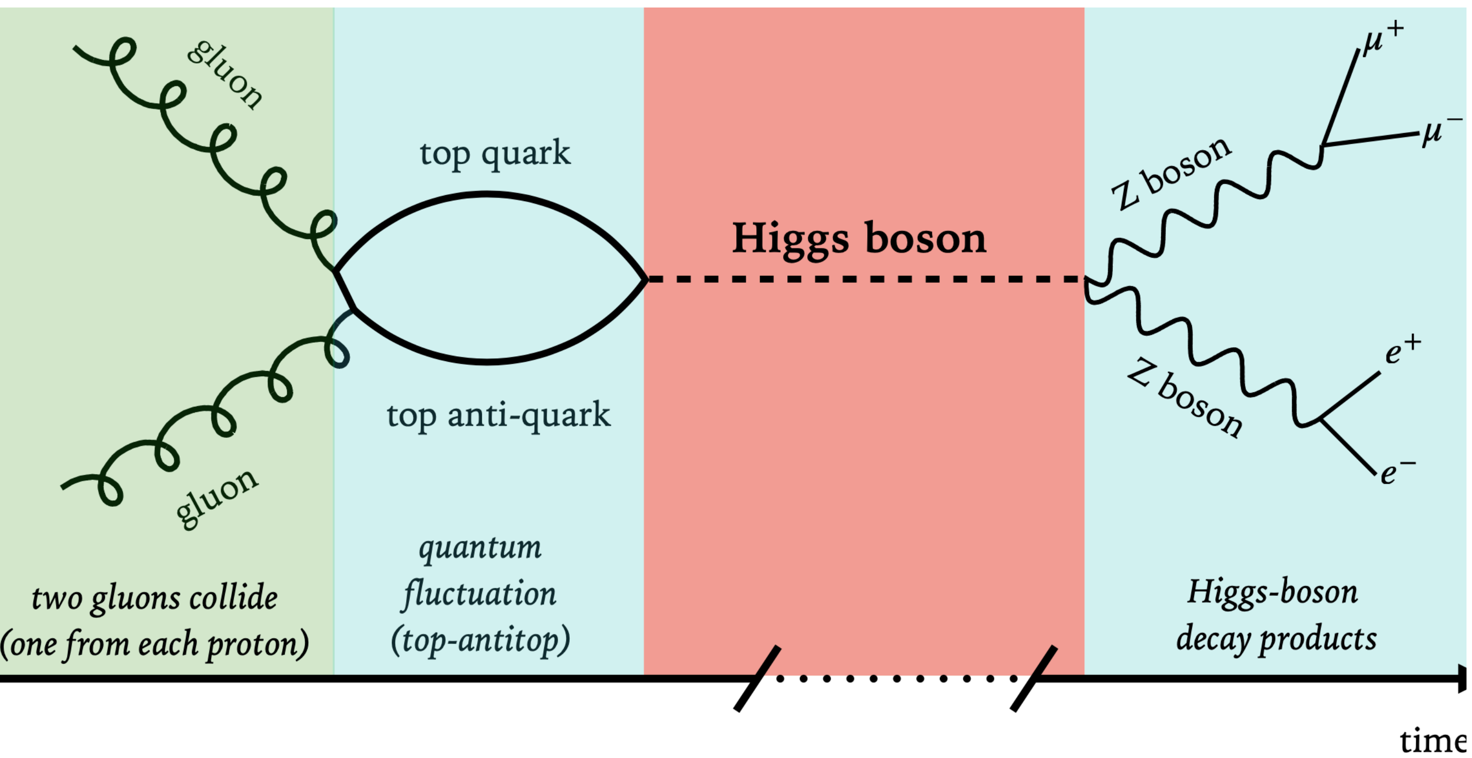
The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2013 to

François Englert and Peter Higgs

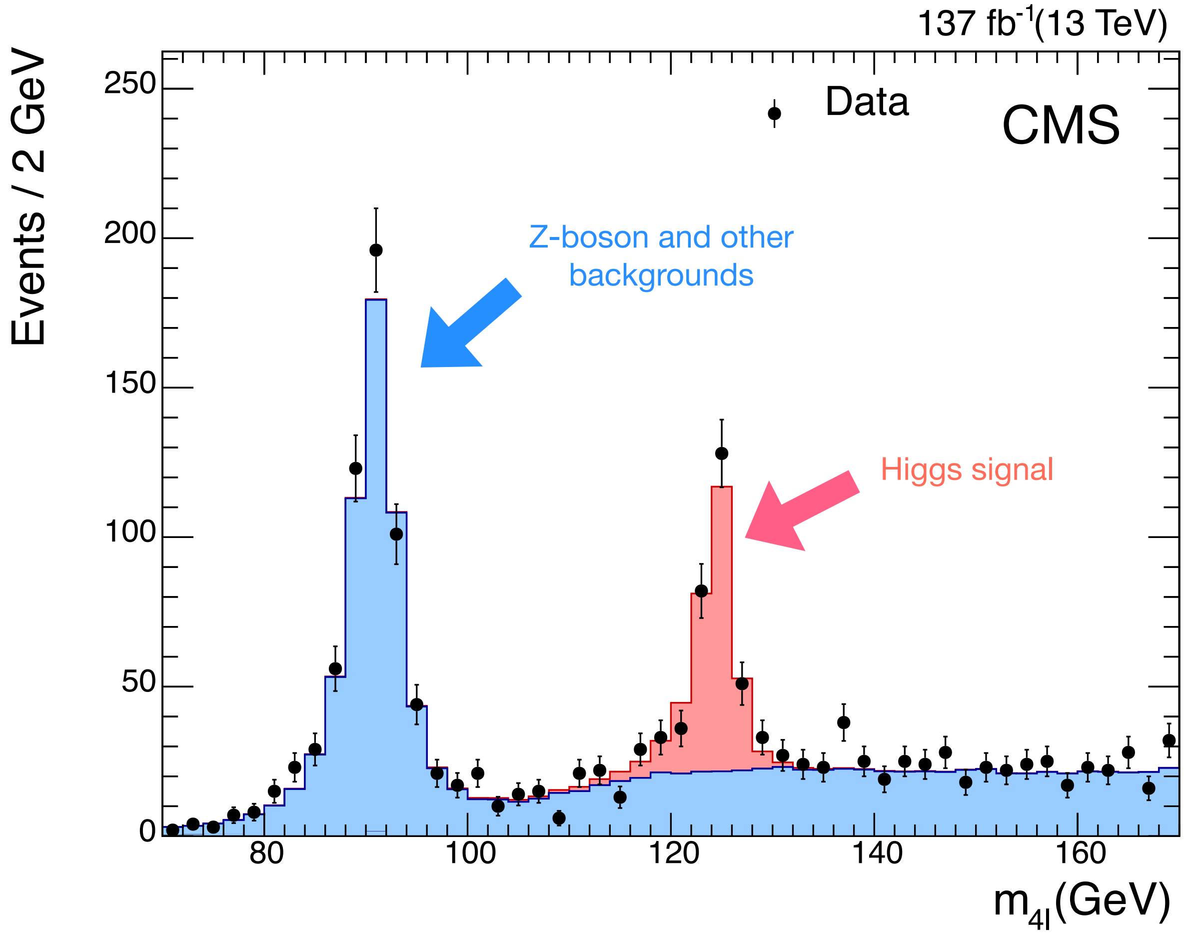
"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"

Learning about the Higgs

Higgs production and decay



Update of Higgs discovery plot



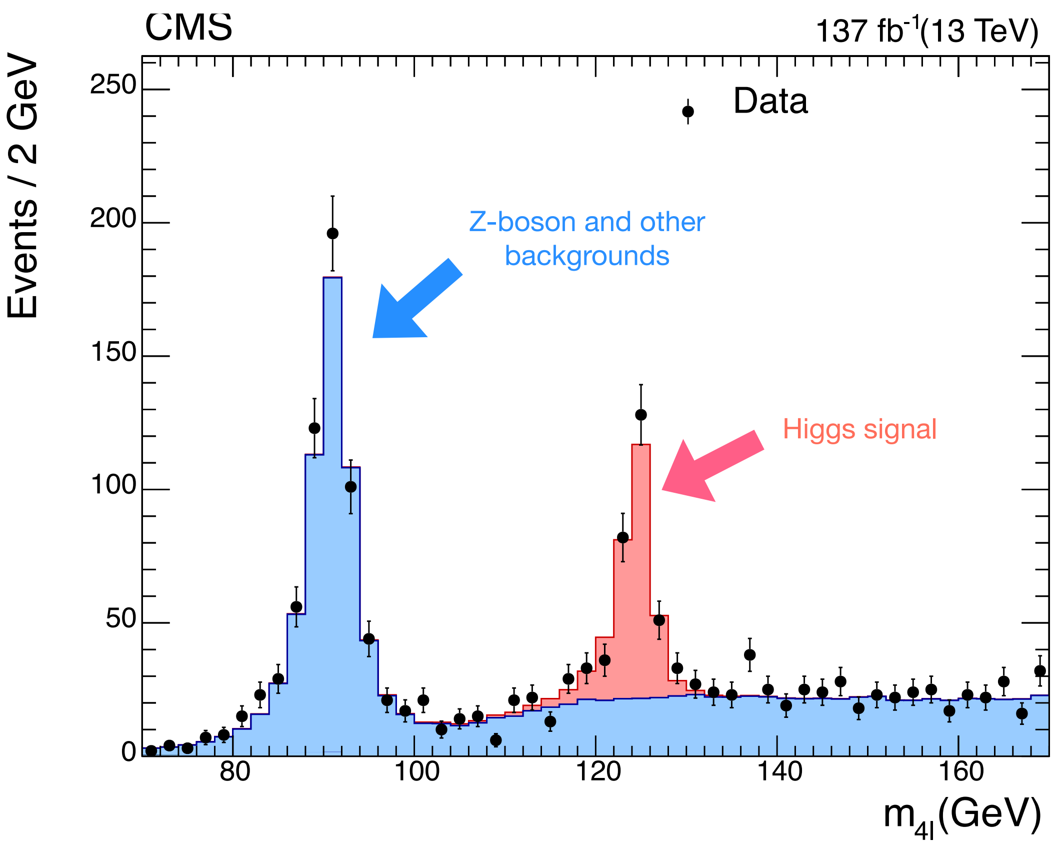
CMS, 2103.04956

[Other crucial discovery channels are the decays to WW and to two photons]

Learning about the Higgs

<u>A lot of information can be extracted</u>

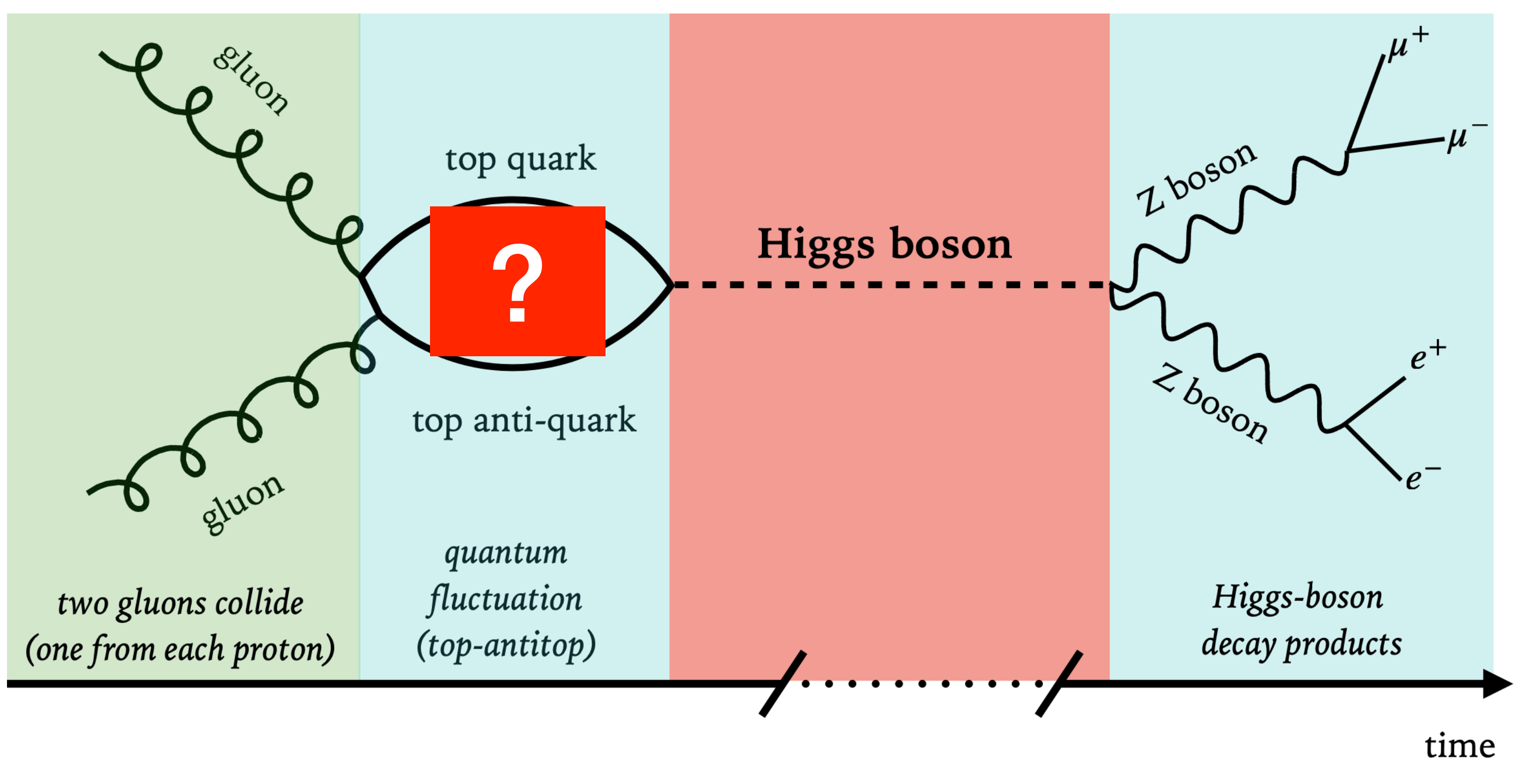
- Existence of the peak: existence of new particle (the Higgs)
- Position of the peak: mass of the Higgs
- Number of events at the peak: information on interaction (the product of) the strength of the Higgs interaction to top and Z bosons
- Angular distributions (not shown) tell us that the Higgs has spin 0



⇒ see talks by S. Dittmer, S. Rosati, A. Tarek, P. Vanlear, …

Caveats

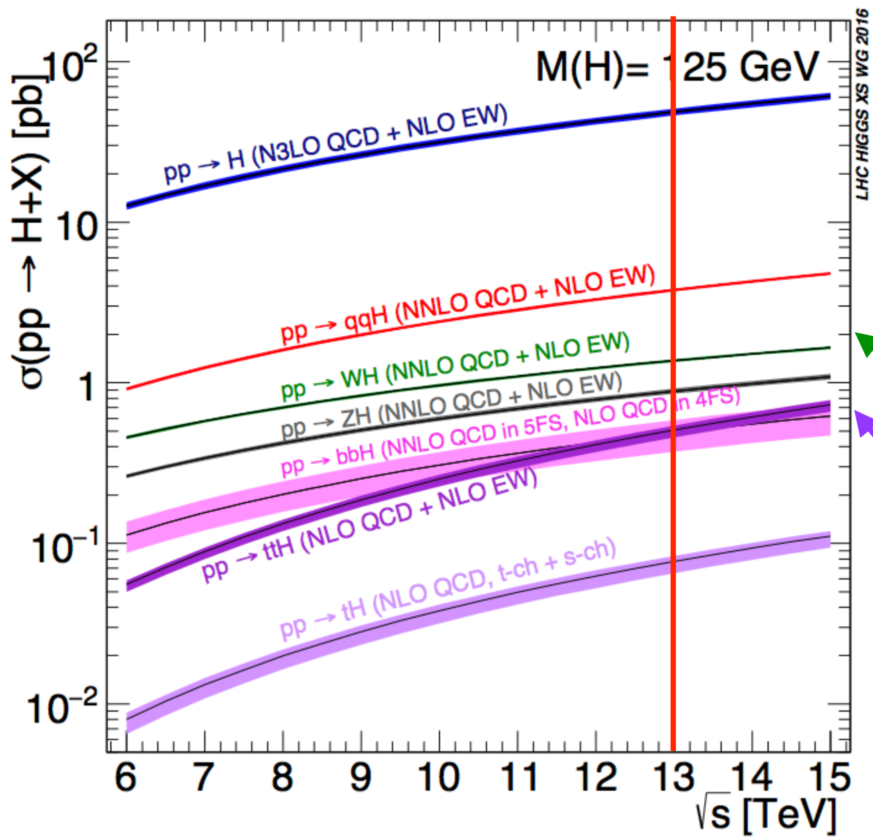
There are a lot of assumptions behind such measurements (e.g. top as quantum fluctuations). Furthermore, only the product of production and decay couplings can be measured.



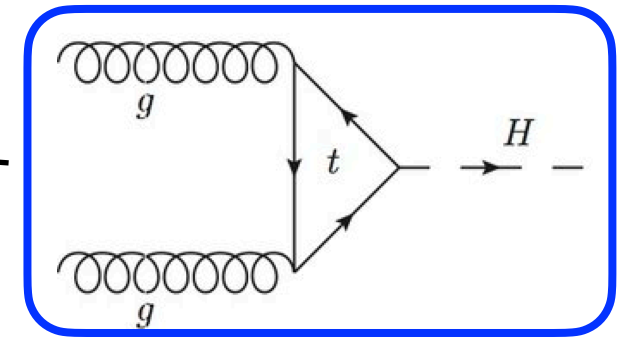
$\sim (g_{ZZH}\ y_t)^2$

For this reason, the LHC experiments study a multitude of Higgs production and decay modes, with complementary sensitivities

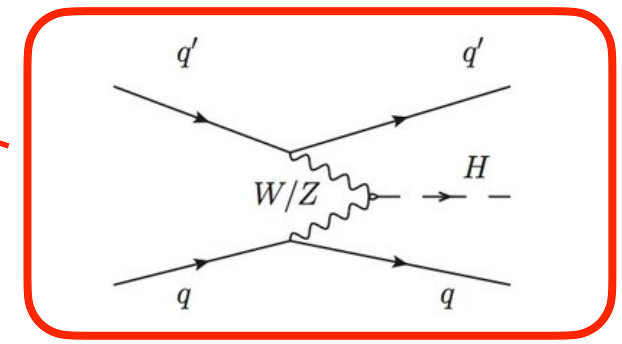
Higgs production



$\sqrt{s}$ (TeV)	Production cross section (in pb) for $m_H = 125\,\text{GeV}$					
	ggF	VBF	WH	ZH	$t\bar{t}H$	total
1.96	$0.95^{+17\%}_{-17\%}$	$0.065^{+8\%}_{-7\%}$	$0.13^{+8\%}_{-8\%}$	$0.079^{+8\%}_{-8\%}$	$0.004^{+10\%}_{-10\%}$	1.23
7	$16.9^{+5\%}_{-5\%}$	$1.24^{+2\%}_{-2\%}$	$0.58^{+3\%}_{-3\%}$	$0.34^{+4\%}_{-4\%}$	$0.09^{+8\%}_{-14\%}$	19.1
8	$21.4^{+5\%}_{-5\%}$	$1.60^{+2\%}_{-2\%}$	$0.70^{+3\%}_{-3\%}$	$0.42^{+5\%}_{-5\%}$	$0.13^{+8\%}_{-13\%}$	24.2
13	$48.6^{+5\%}_{-5\%}$	$3.78^{+2\%}_{-2\%}$	$1.37^{+2\%}_{-2\%}$	$0.88^{+5\%}_{-5\%}$	$0.50^{+9\%}_{-13\%}$	55.1
14	$54.7^{+5\%}_{-5\%}$	$4.28^{+2\%}_{-2\%}$	$1.51^{+2\%}_{-2\%}$	$0.99^{+5\%}_{-5\%}$	$0.60^{+9\%}_{-13\%}$	62.1



N3LO



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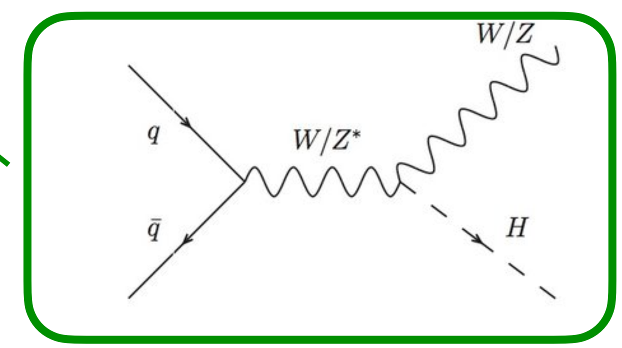
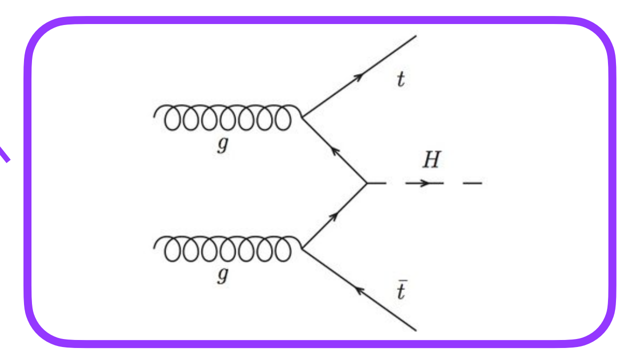
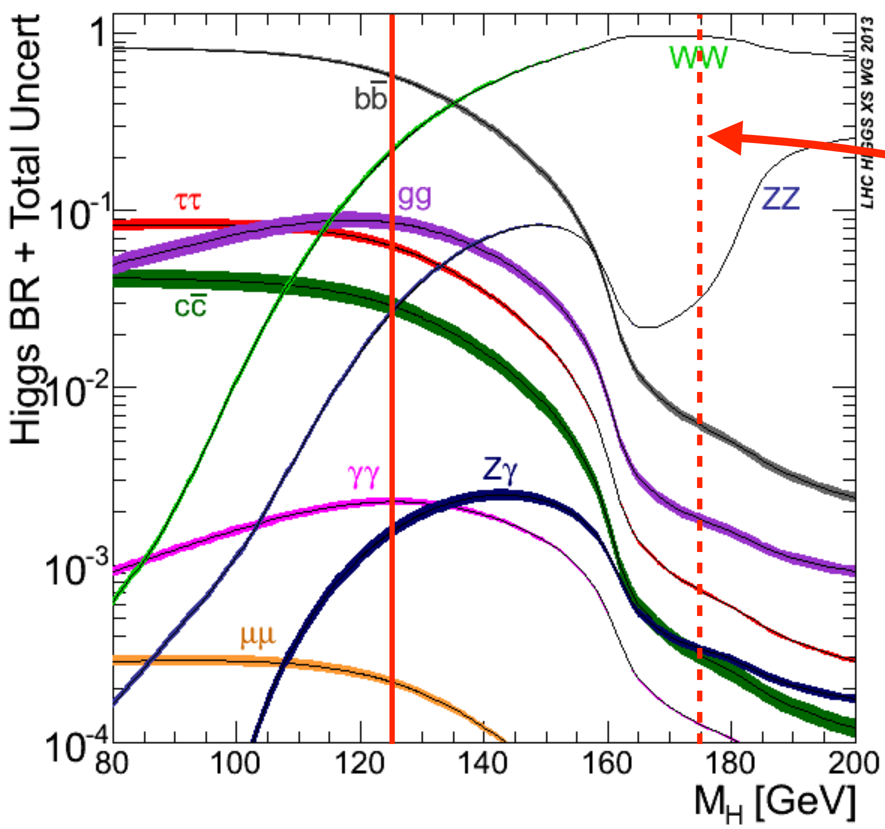


NNLO



NLO + approx NNLO

Higgs decays

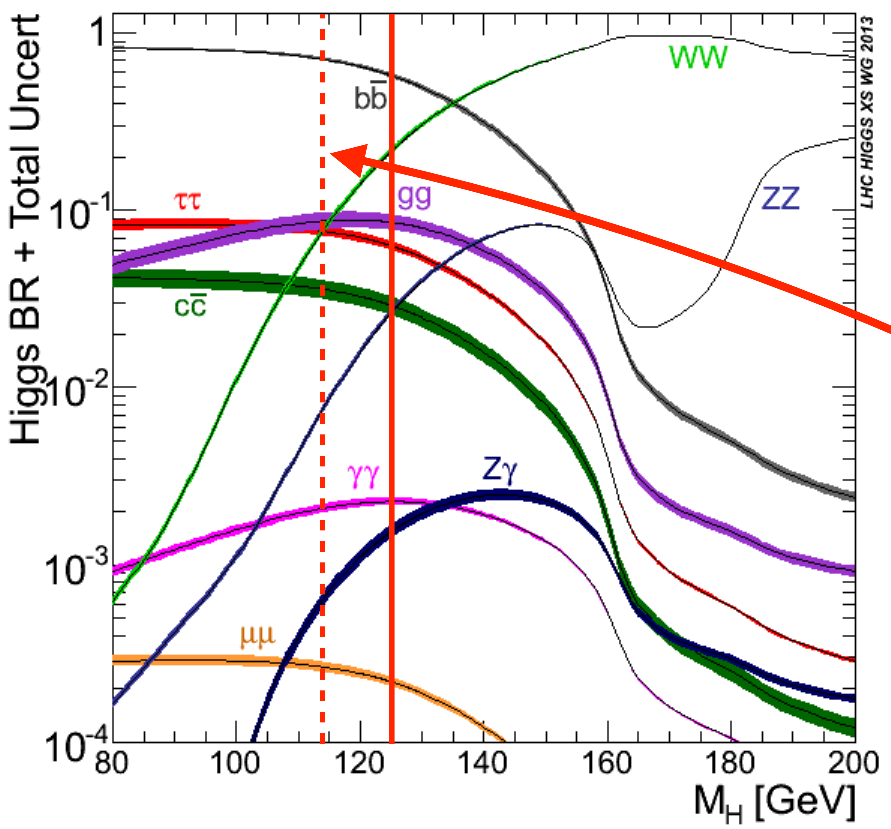


Decay channel	Branching ratio	Rel. uncertainty
$H \to \gamma\gamma$	2.27×10^{-3}	$^{+5.0\%}_{-4.9\%}$
$H \to ZZ$	2.62×10^{-2}	$^{+4.3\%}_{-4.1\%}$
$H \to W^+W^-$	2.14×10^{-1}	$^{+4.3\%}_{-4.2\%}$
$H \to \tau^+\tau^-$	6.27×10^{-2}	$^{+5.7\%}_{-5.7\%}$
$H \to b\bar{b}$	5.84×10^{-1}	$^{+3.2\%}_{-3.3\%}$
$H \to Z\gamma$	1.53×10^{-3}	$^{+9.0\%}_{-8.9\%}$
$H \to \mu^+\mu^-$	2.18×10^{-4}	$^{+6.0\%}_{-5.9\%}$

Higgs mass lies in a lucky spot:

- Had the Higgs boson been 50 GeV heavier, it would have been impossible to detect more than just two basic channels (ZZ and WW)
- Had the Higgs been just 10 GeV lighter, the decays to WW and ZZ would have been impossible so far

Higgs decays



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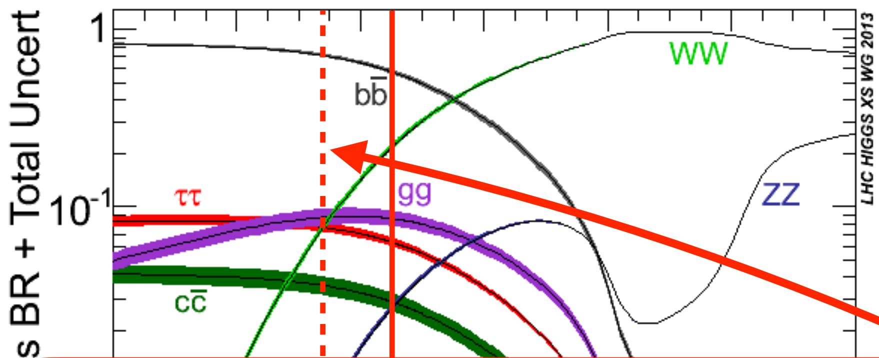

<u>Higgs mass lies in a lucky spot:</u>

The value of the Higgs mass chosen by Nature is part of the reason why the Higgs boson was discovered so quickly and why LHC could establish much more than originally foreseen in just ten years

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LHC

Thanks to a Nature and to excellent performances of the accelerator machine, detector experiments and enormous progress in computer capabilities precision at the LHC is a reality.

This is a game changer

- precision measurements of Higgs fundamental properties (required to characterise the nature of the Higgs)
- precision tests to look for sign of BSM in the Higgs sector

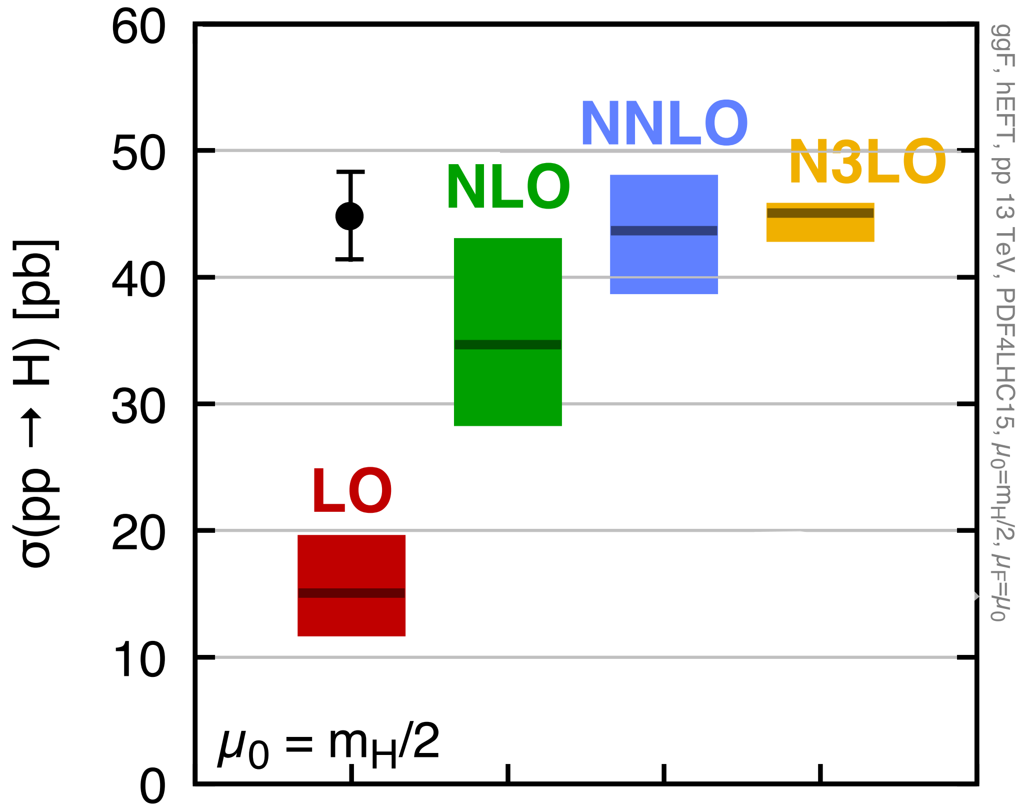
In this endeavour precision theory predictions are crucial to enhance sensitivity

The potential of the LHC and HL-LHC programme cannot be fully exploited without precision theory predictions

Precision calculations

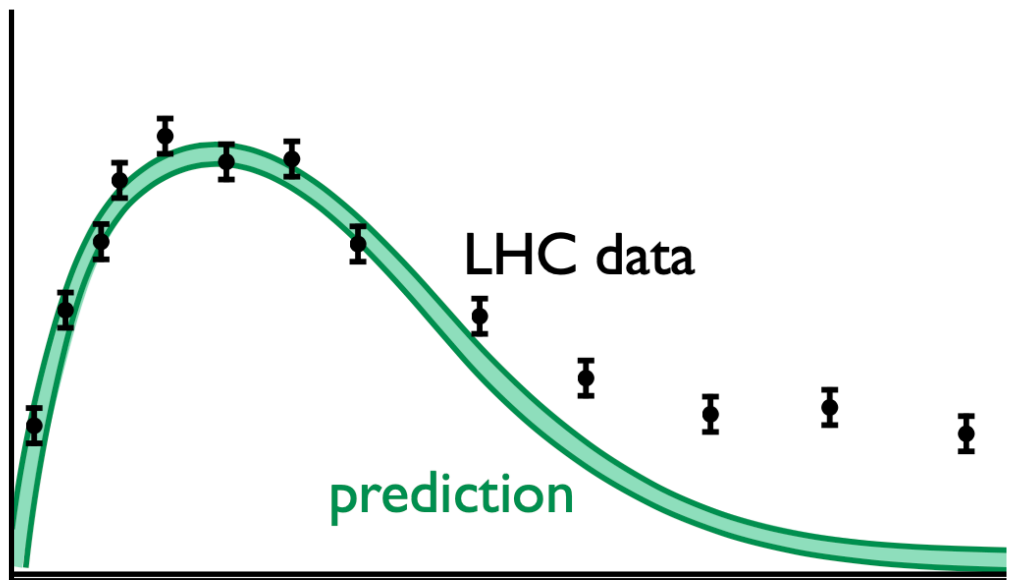
Enormous progress in having a theoretically precise description of Higgs production, Higgs decays and relevant background processes.

The role of precision at the LHC can not be understated.



Role of precision

Gedankenexperiment:



adapted from M. Wiesemann

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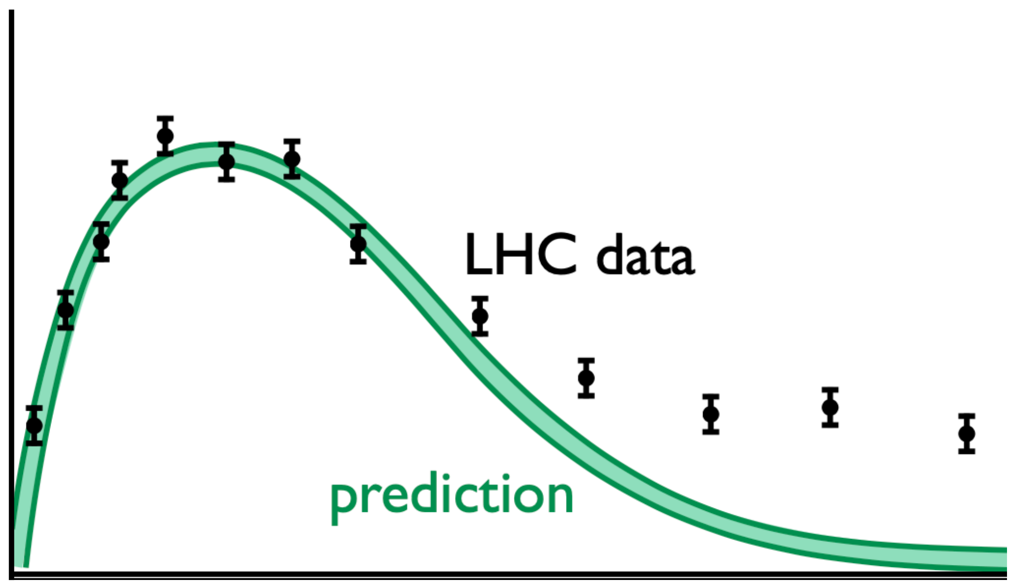

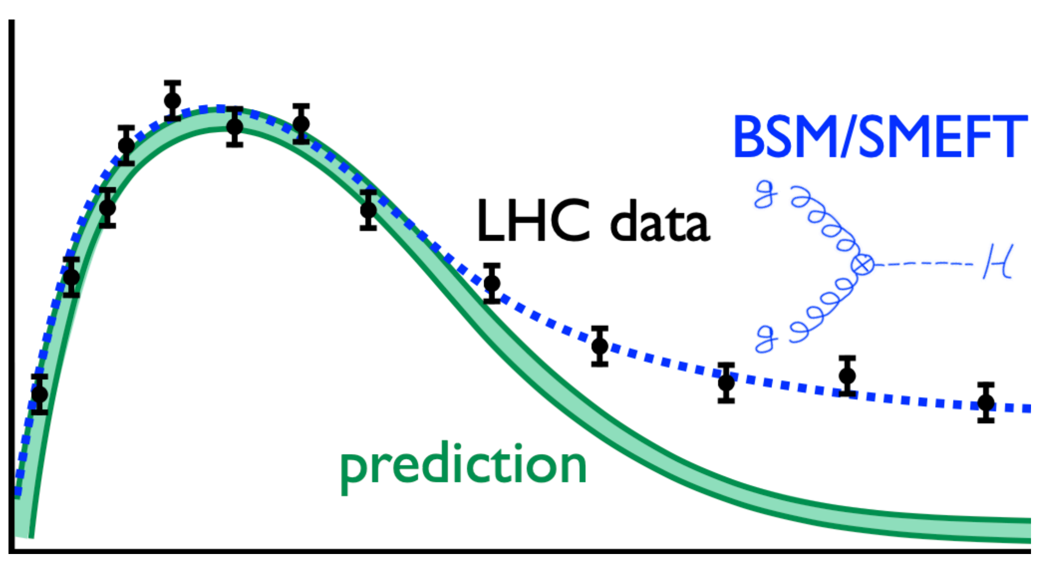

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Role of precision

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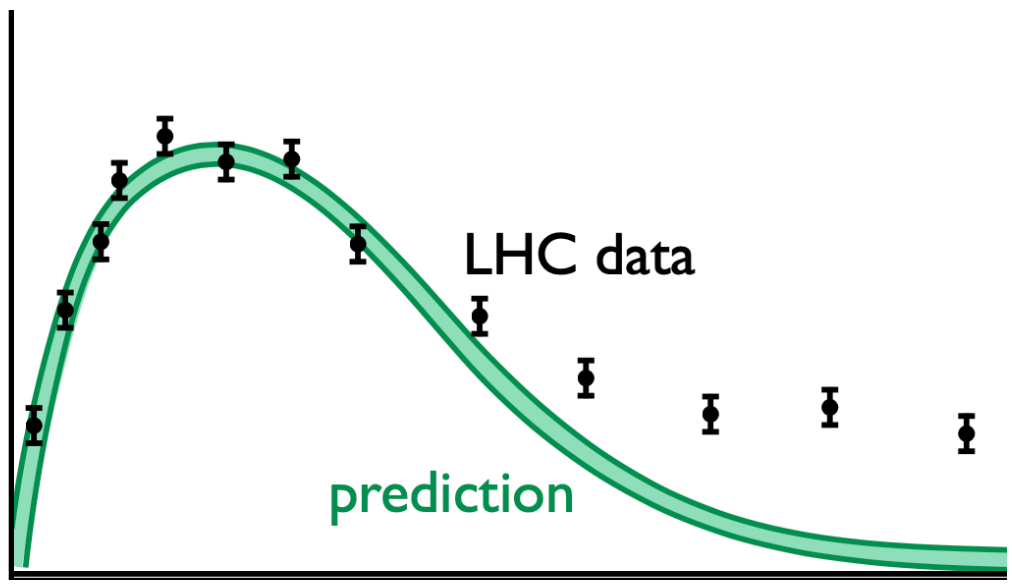
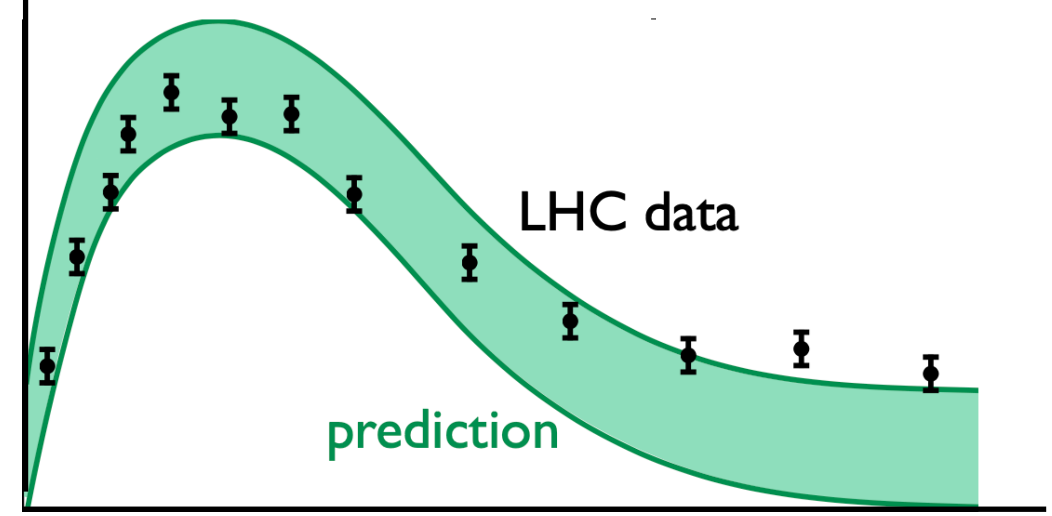
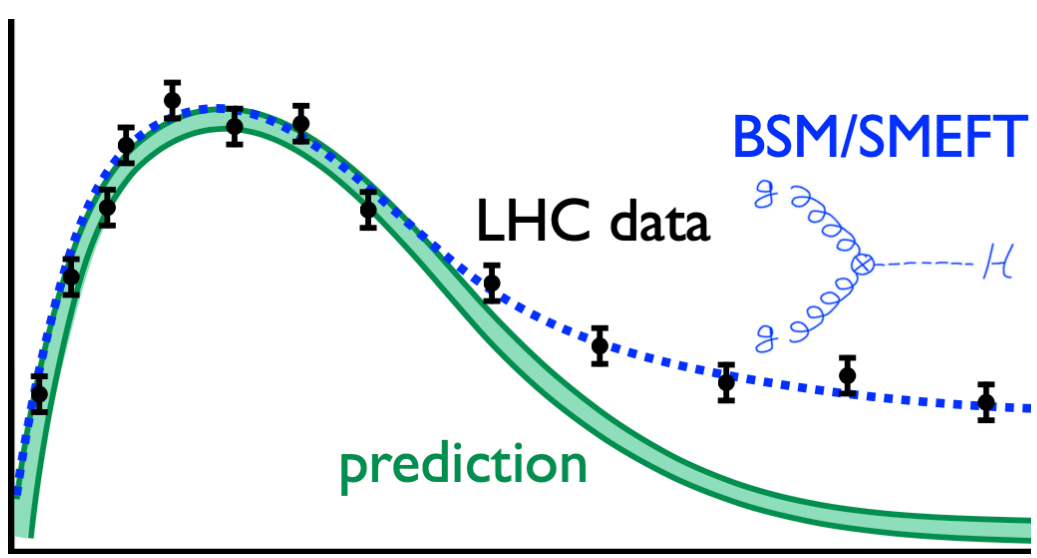


Theory with 5 times



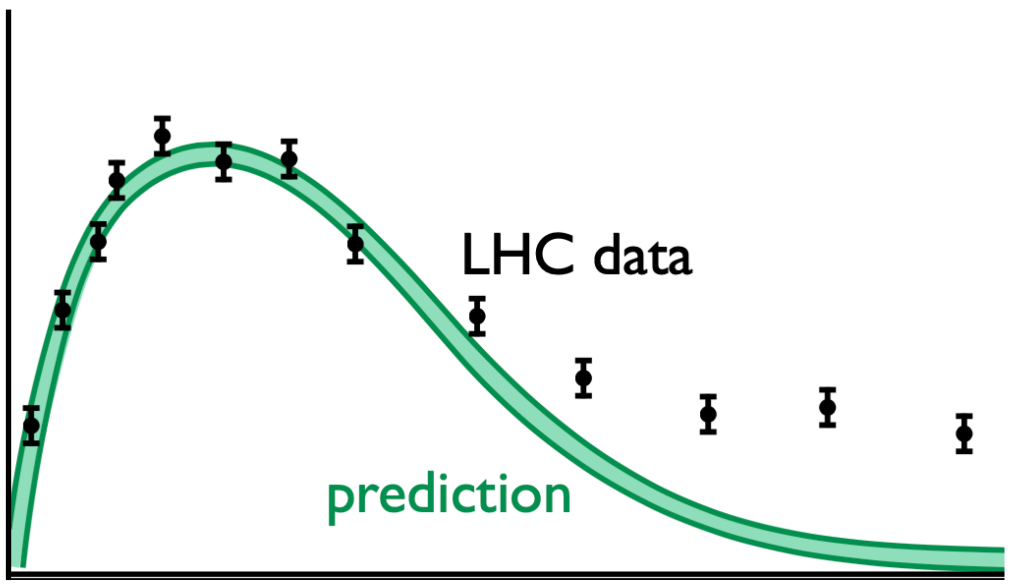
⇒ miss discovering new physics

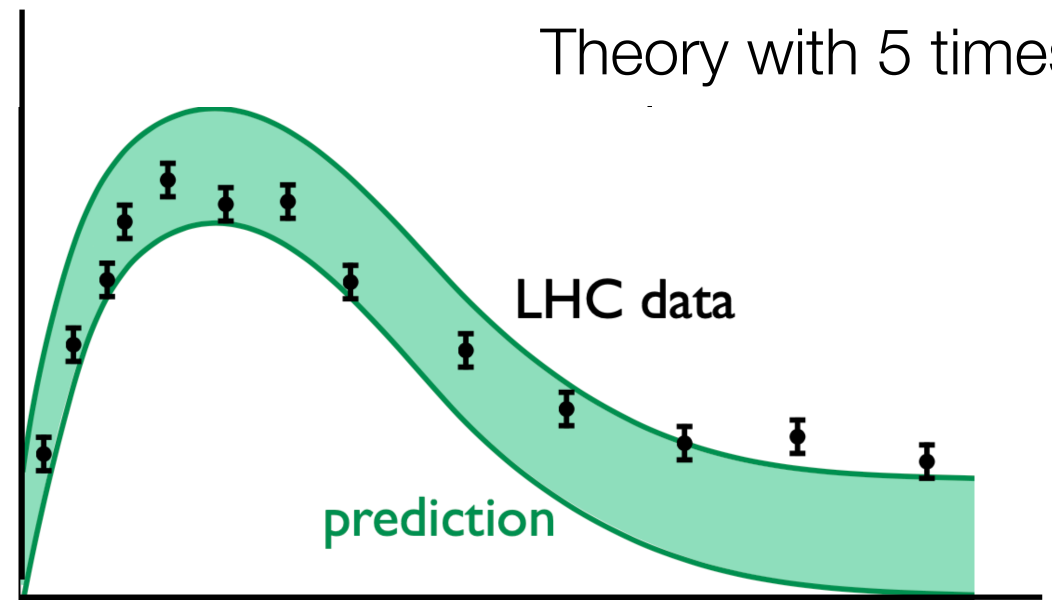


adapted from M. Wiesemann

Role of precision

Gedankenexperiment:





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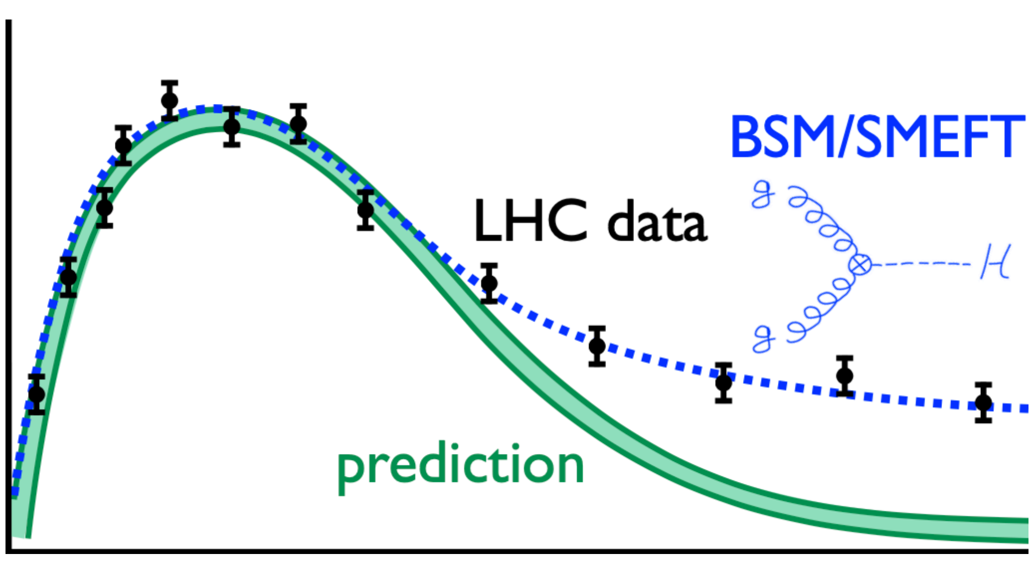


Higher precision can translate into higher discovery reach almost "for free"

adapted from M. Wiesemann

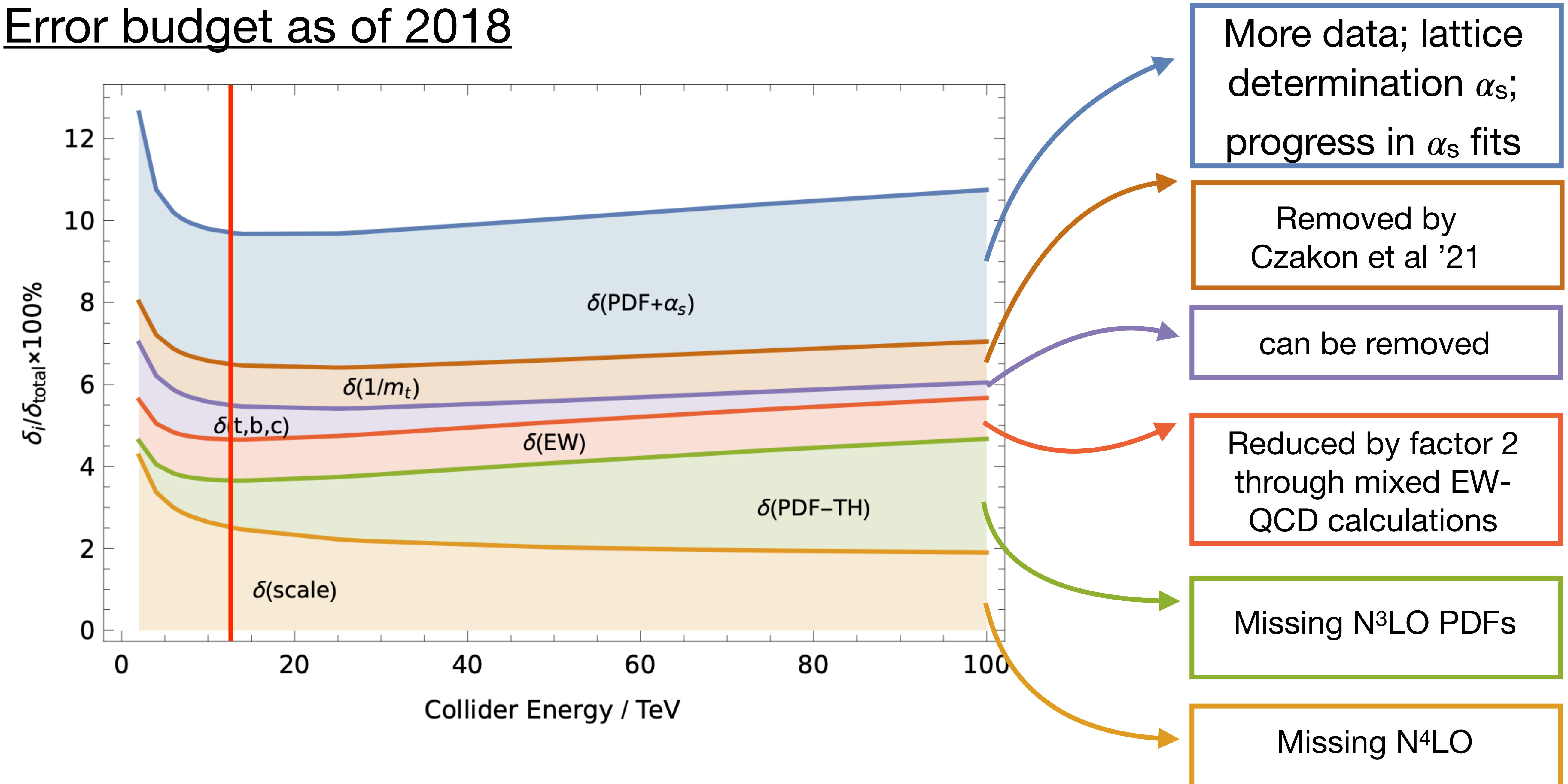
Precision theory: a multilateral challenge

- pushing frontier to N^3LO in the perturbative expansion
- heavy-top and bottom mass effects
- mixed QCD-electroweak corrections
- large logarithmically enhanced terms to all orders
- fully exclusive description of the final state through parton showers
  - improving the accuracy of parton showers
  - matching fixed-order calculations and parton showers
- modelling of hadronization effects, multi-parton interactions (or ways to reduce the effects)
- Uncertainties due to input in the predictions (strong coupling, PDF, b-mass…) $\Rightarrow$ ways to reduce these uncertainties
- …

Error budget: one example

Gluon-fusion Higgs productions (known to N3LO fully differential)

Error budget as of 2018



Dulat, Lazopoulos, Mistlberger '18

Precision calculations

The role of precision at the LHC can not be understated. It simply increases the discovery reach of the machine, *“almost” for free …*

For an overview of the recent progress and prospect on this

⇒ see talk by R. Harlander

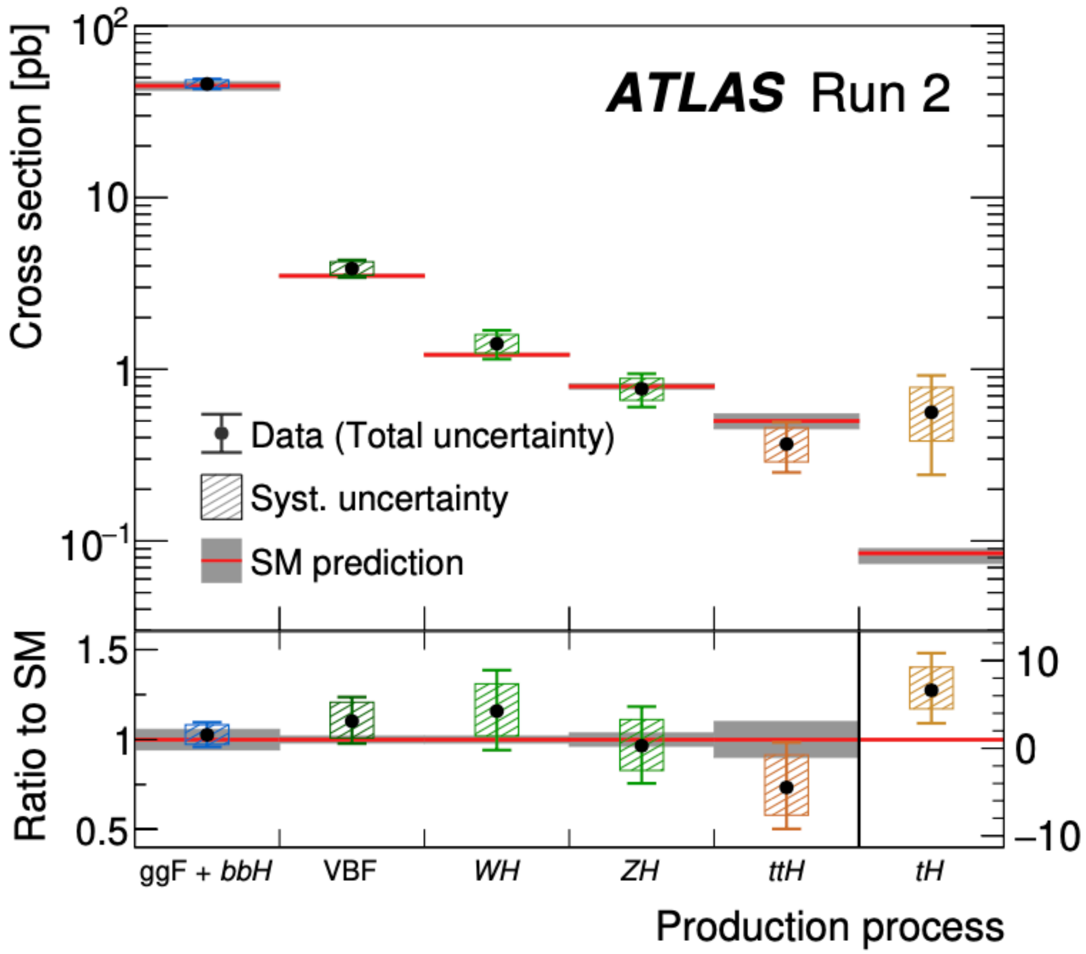
For evolution in experimental techniques since discovery

⇒ see talk by F. Cerutti

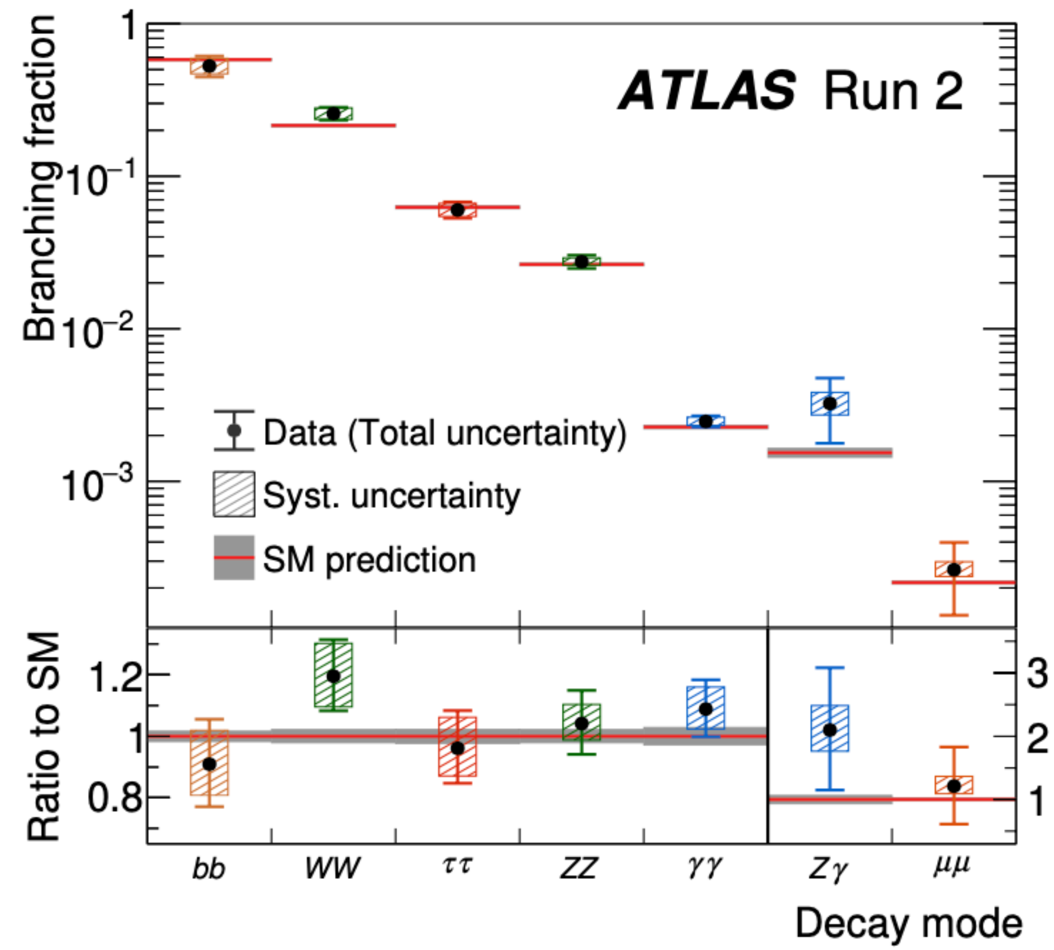
Where do we stand after ten years?

Higgs production & decay

Cross-sections



Branching ratios

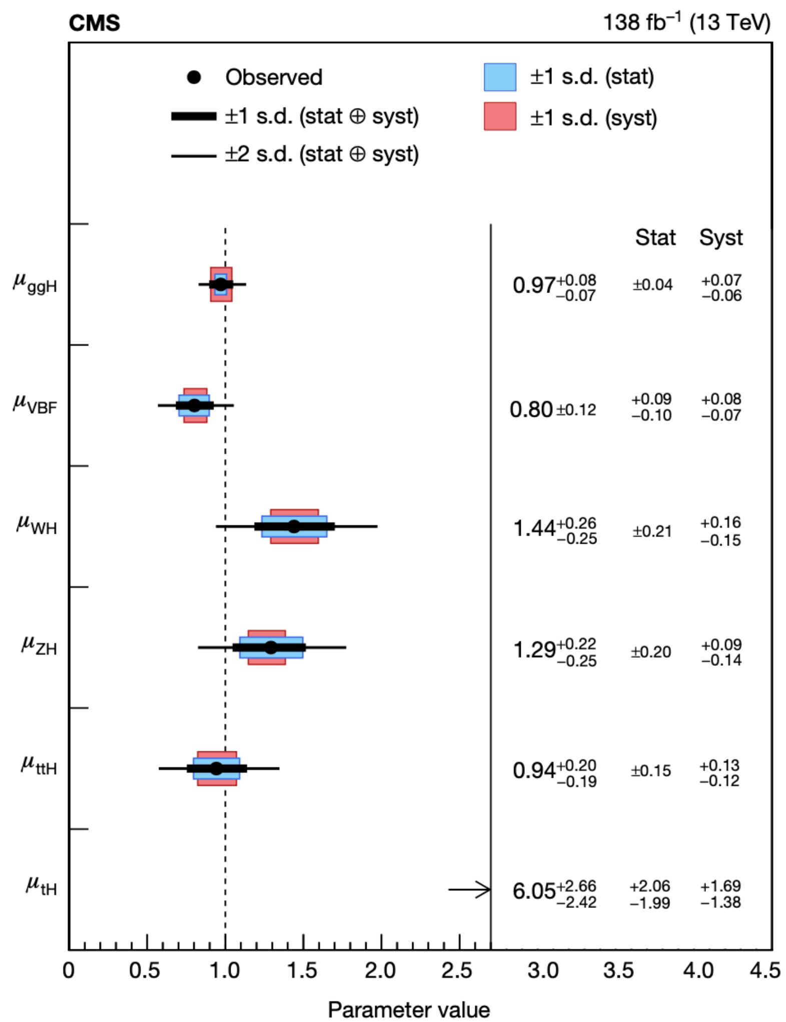


ATLAS *Nature* 607 (2022) 7917

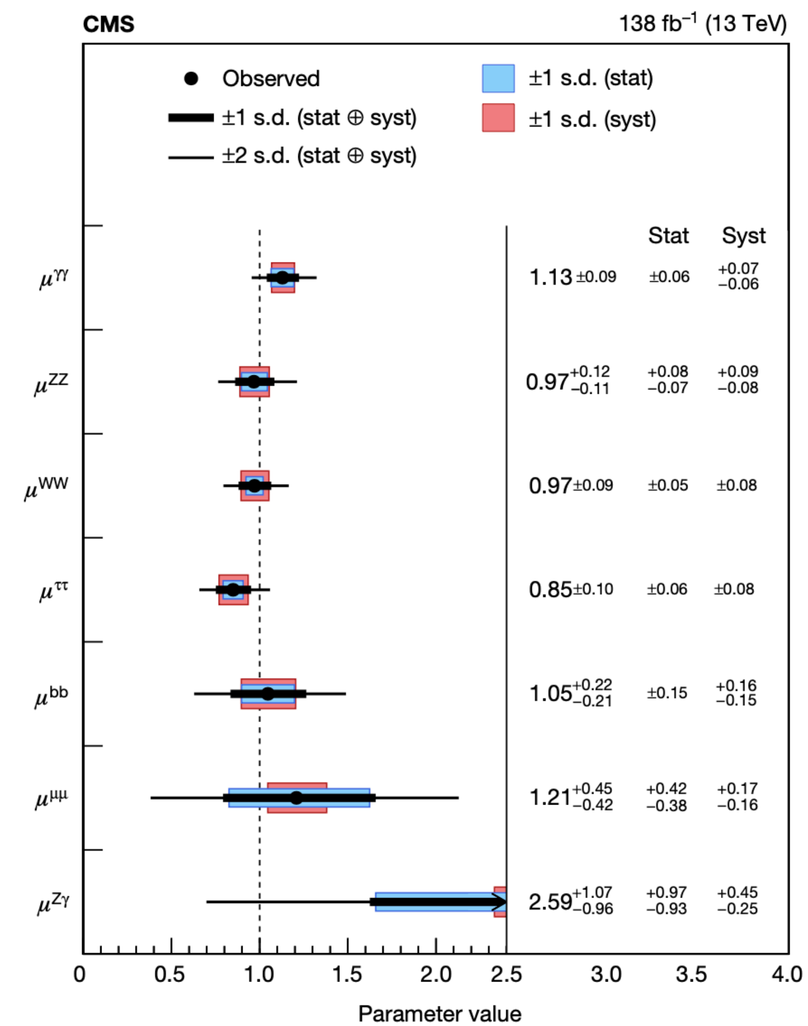
A large number of Higgs production and decay modes have been established. Excellent agreement with theory predictions.

Higgs production & decay

<u>Signal strength (production)</u>



<u>Signal strength (decay)</u>



CMS *Nature* 607 (2022) 7917

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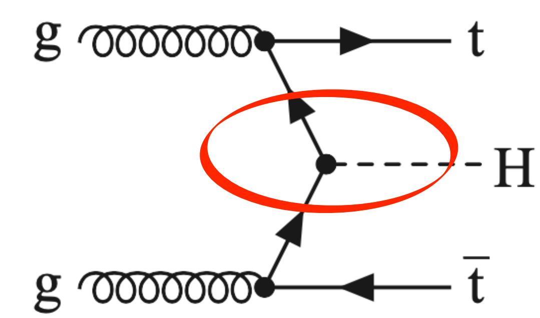
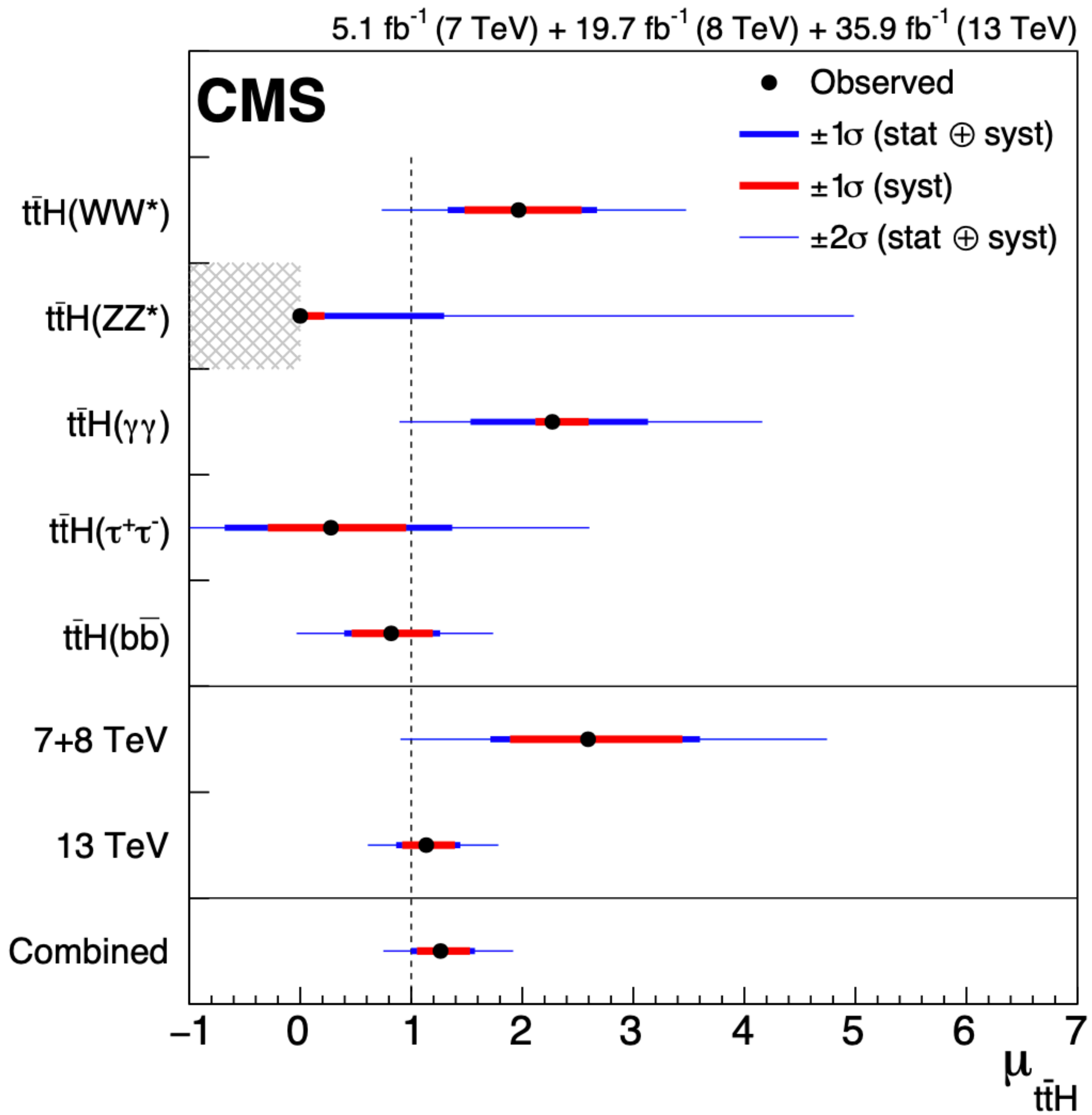
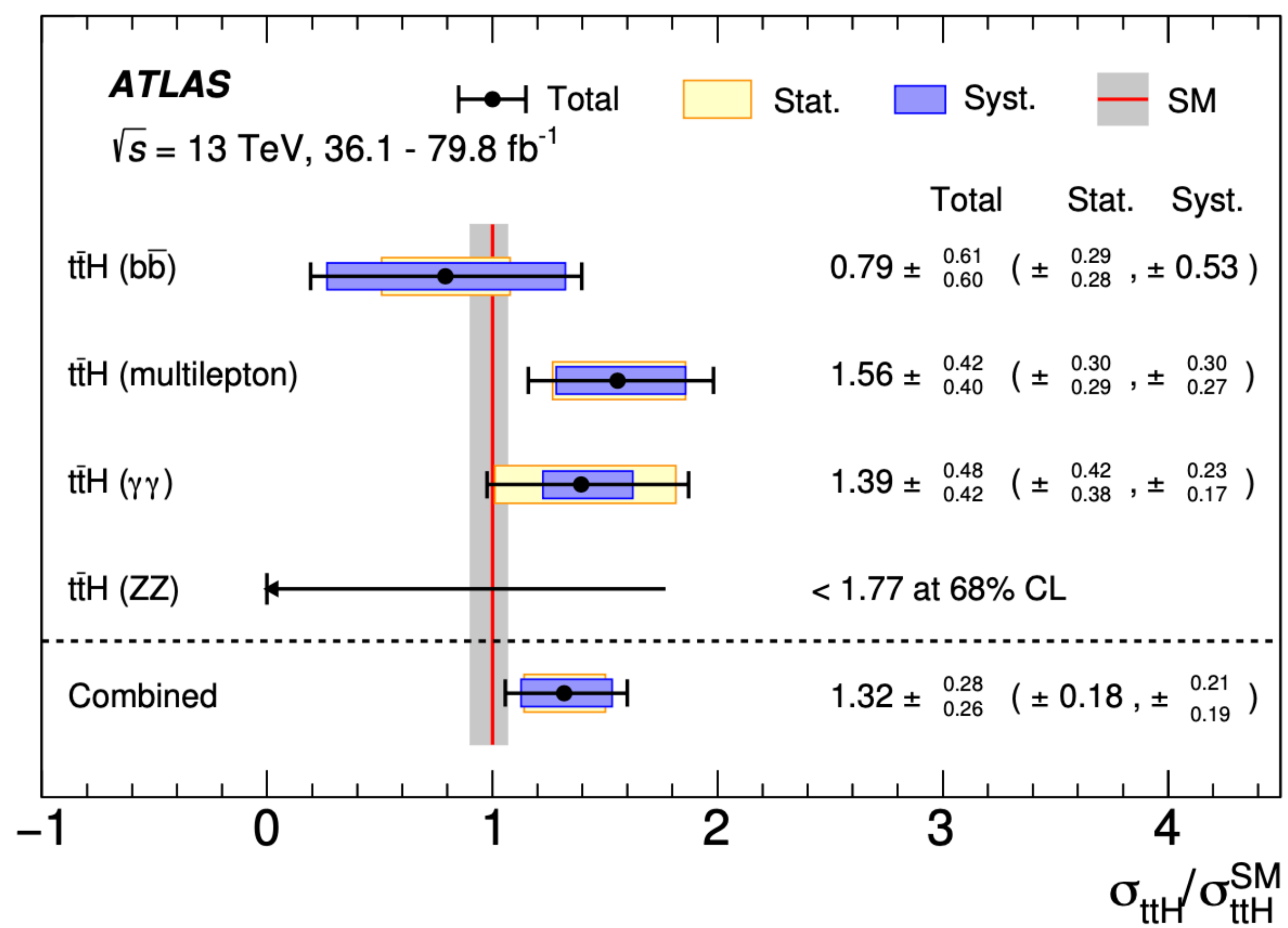
Highlights: ttH



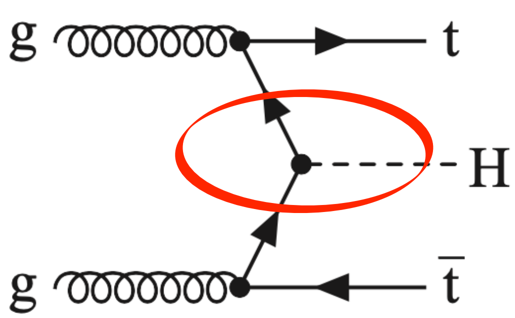




CMS, Phys. Rev. Lett. 120, 231801 (2018)

ATLAS, Phys. Lett. B 784 (2018) 173

Highlights: ttH



The observation of Higgs boson production in association with a top quark-antiquark pair is reported, based on a combined analysis of proton-proton collision data at center-of-mass energies of $\sqrt{s}$=7, 8, and 13 TeV, corresponding to integrated luminosities of up to 5.1, 19.7, and 35.9 fb−1, respectively. The data were collected with the CMS detector at the CERN LHC. The results of statistically independent searches for Higgs bosons produced in conjunction with a top quark-antiquark pair and decaying to pairs of W bosons, Z bosons, photons, τ leptons, or bottom quark jets are combined to maximize sensitivity. An excess of events is observed, with a significance of 5.2 standard deviations, over the expectation from the background-only hypothesis. The corresponding expected significance from the standard model for a Higgs boson mass of 125.09 GeV is 4.2 standard deviations. The combined best fit signal strength normalized to the standard model prediction is 1.26+0.31−0.26.

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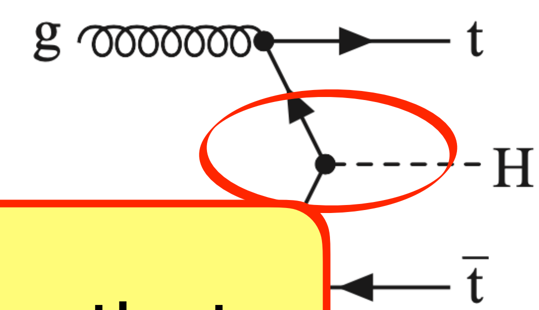
The observation of Higgs boson production in association with a top quark pair ($t\bar{t}H$), based on the analysis of proton-proton collision data at a centre-of-mass energy of 13 TeV recorded with the ATLAS detector at the Large Hadron Collider, is presented. Using data corresponding to integrated luminosities of up to 79.8 fb−1, and considering Higgs boson decays into $b\bar{b}$, WW^*, ττ, γγ , and ZZ^*, the observed significance is 5.8 standard deviations, compared to an expectation of 4.9 standard deviations. Combined with the $t\bar{t}H$ searches using a dataset corresponding to integrated luminosities of 4.5 fb−1 at 7 TeV and 20.3 fb−1 at 8 TeV, the observed (expected) significance is 6.3 (5.1) standard deviations. Assuming Standard Model branching fractions, the total $t\bar{t}H$ production cross section at 13 TeV is measured to be 670± 90 (stat.) +110 −100 (syst.) fb, in agreement with the Standard Model prediction.

ATLAS, Phys. Lett. B 784 (2018) 173

Highlights: ttH



The measurement of yet one more process that agrees with Standard Model predictions

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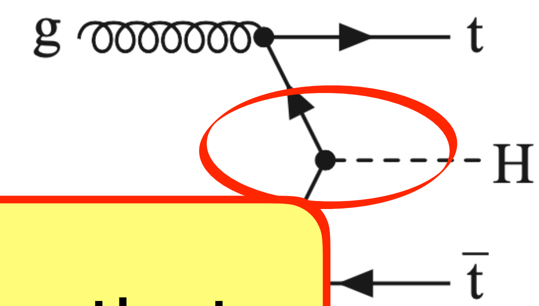

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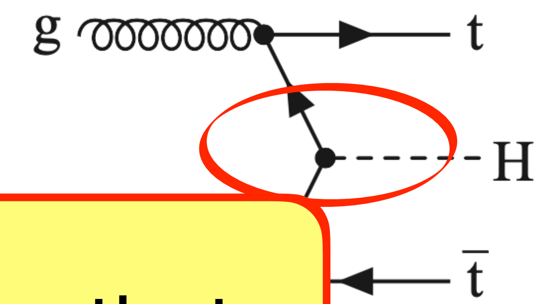
OR

CMS, Phys. Rev. Lett. 120, 231801 (2018)

The observation of Higgs boson production in association with a top quark pair (tt¯H), based on the analysis of proton-proton collision data at a centre-of-mass energy of 13 TeV recorded with the ATLAS detector at the Large Hadron Collider, is presented. Using data corresponding to integrated luminosities of up to 79.8 fb−1, and considering Higgs boson decays into bb¯, WW∗, ττ, γγ , and ZZ∗, the observed significance is 5.8 standard deviations, compared to an expectation of 4.9 standard deviations. Combined with the tt¯H searches using a dataset corresponding to integrated luminosities of 4.5 fb−1 at 7 TeV and 20.3 fb−1 at 8 TeV, the observed (expected) significance is 6.3 (5.1) standard deviations. Assuming Standard Model branching fractions, the total tt¯H production cross section at 13 TeV is measured to be 670± 90 (stat.) +110 −100 (syst.) fb, in agreement with the Standard Model prediction.

ATLAS, Phys. Lett. B 784 (2018) 173

Highlights: ttH



The measurement of yet one more process that agrees with Standard Model predictions

The observatic ... lysis of
proton–proton ... p to 5.1, 19.7,
and 35.9 fb−1 ... dent searches
for Higgs bosons produced in conjunction with a top quark–antiquark pair and decaying to pairs of W bosons, Z bosons, photons, τ leptons, or bottom quark jets are combined to maximize sensitivity. A ... s observed, with a significance of 5.2 standard deviations, over the expectation from the background-only hypothesis. T ... xpected significance from the standard model for a Higgs boson mass of 125.09 GeV is 4.2 standard deviations. The co ... al strength normalized to the standard model prediction is 1.26+0.31−0.26.

OR

CMS, Phys. Rev. Lett. 120, 231801 (2018)

The direct evidence of a new fundamental interaction (the Yukawa interaction) which couples the Higgs to the heaviest known quark?

The observatic ... ollision data at a
centre-of-mas ... sponding to
integrated lum ... significance is
5.8 standard d ... et
corresponding ... 6.3 (5.1)
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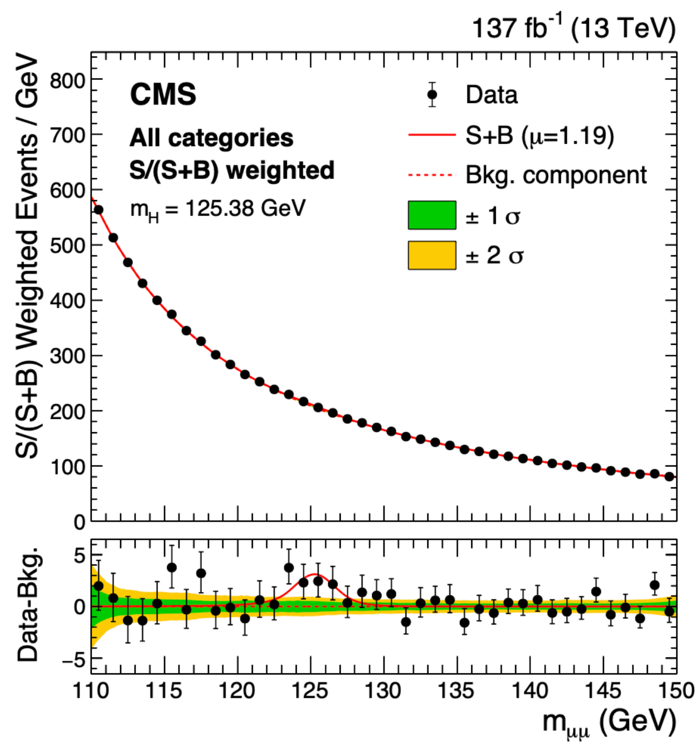
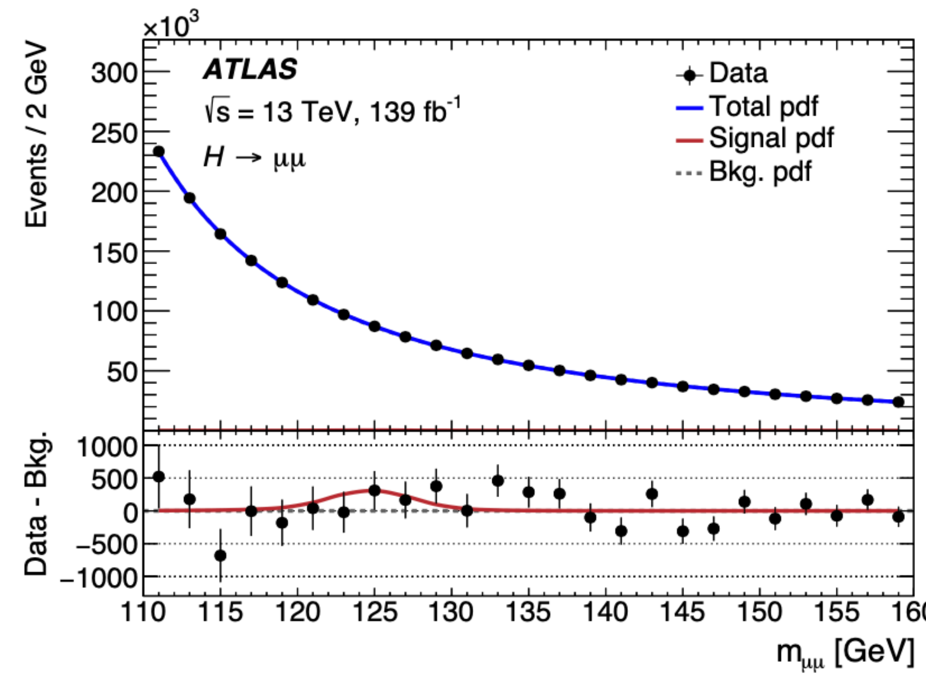
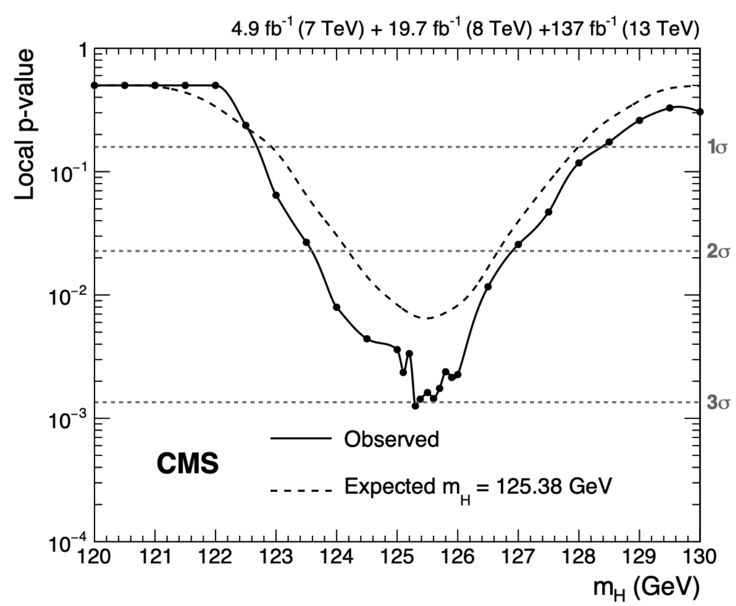
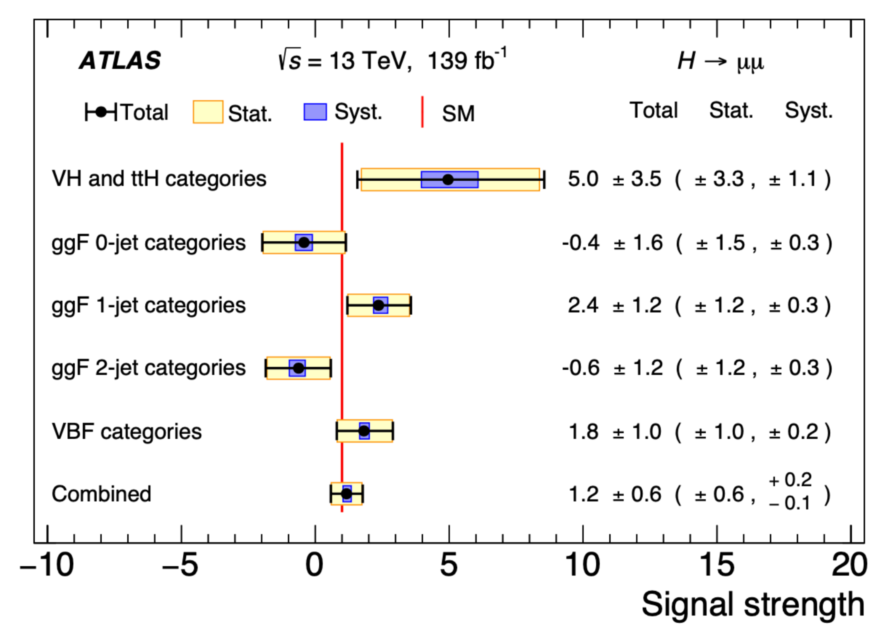
ATLAS, Phys. Lett. B 784 (2018) 173

Recent highlights: H→μμ







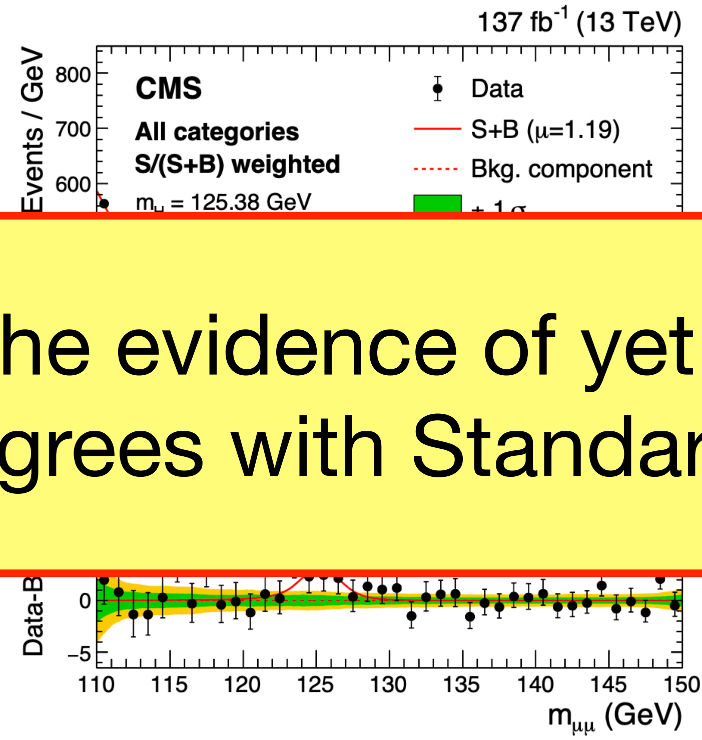


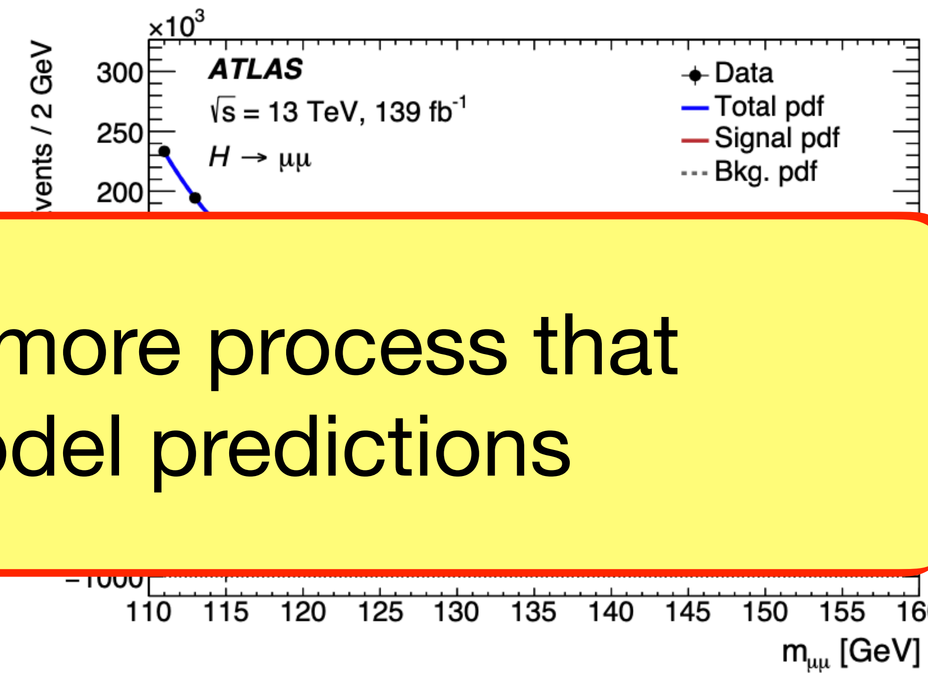
CMS, 2205.05550

ATLAS, 2007.07830

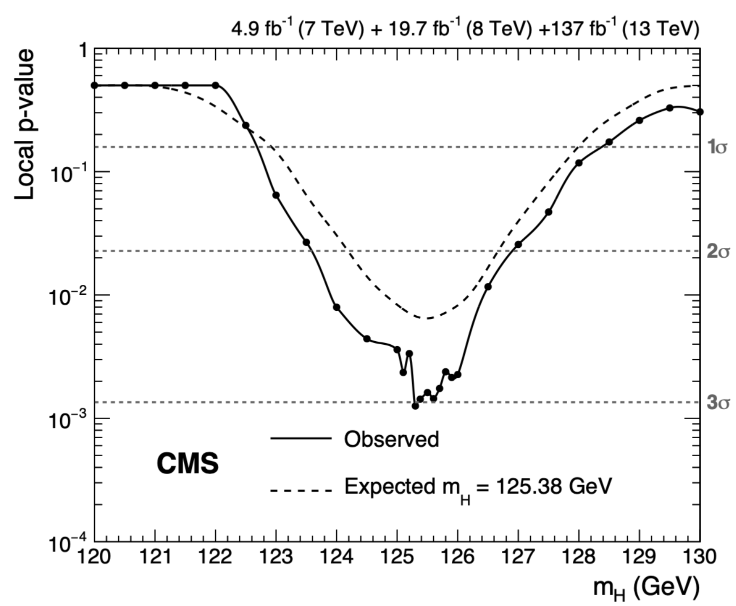
Role of precision theory predictions rather limited

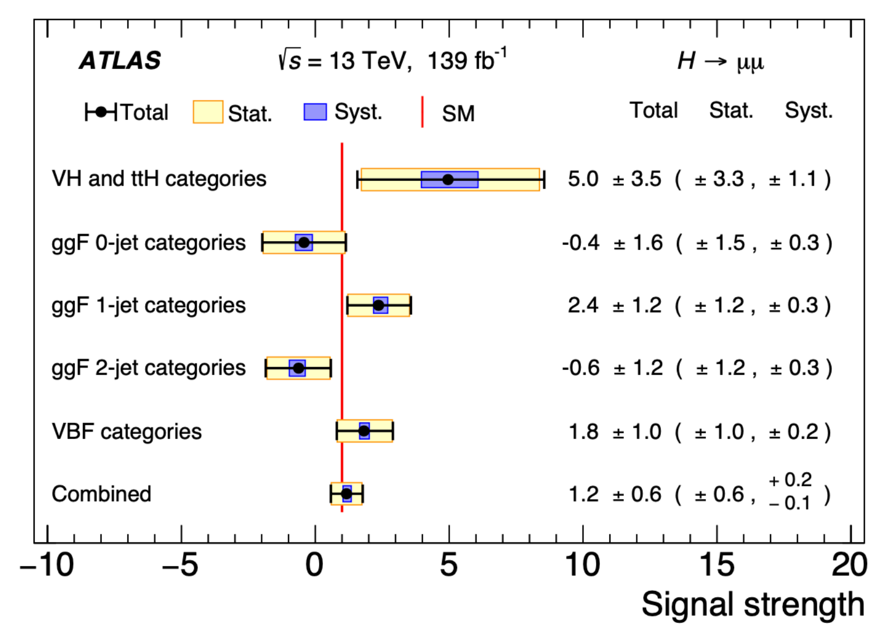
Recent highlights: H→μμ





The evidence of yet one more process that agrees with Standard Model predictions





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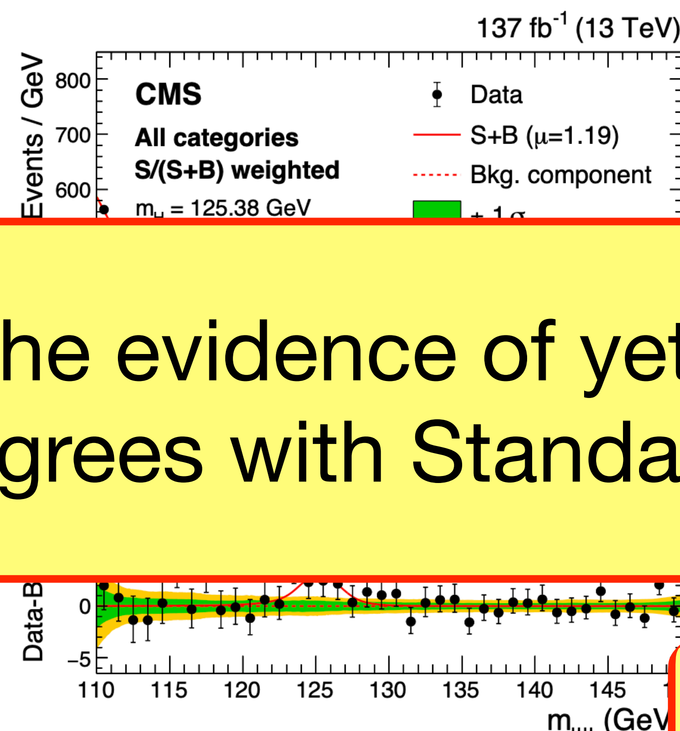

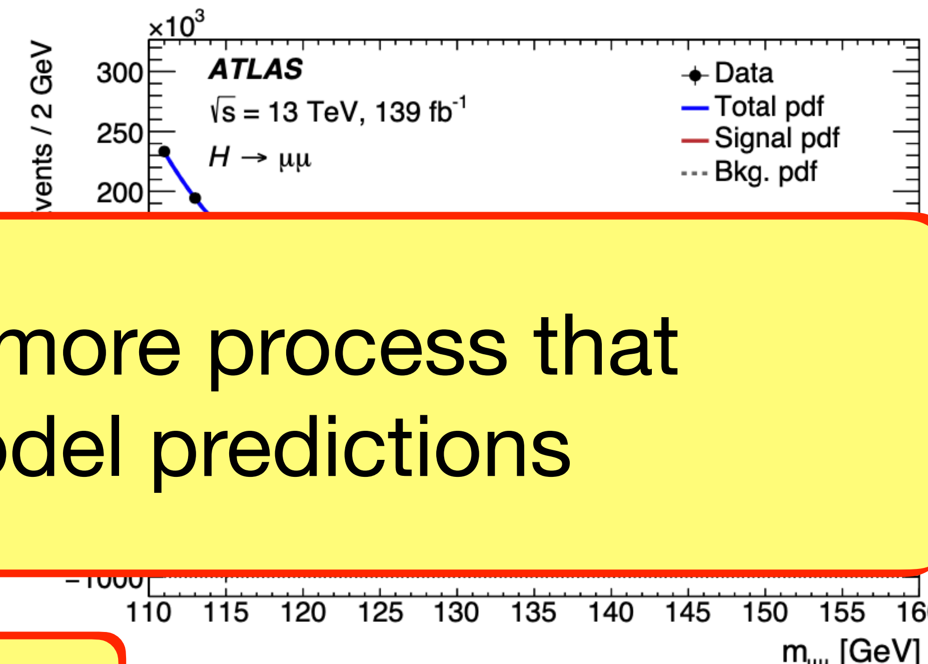

The evidence of yet one more process that agrees with Standard Model predictions

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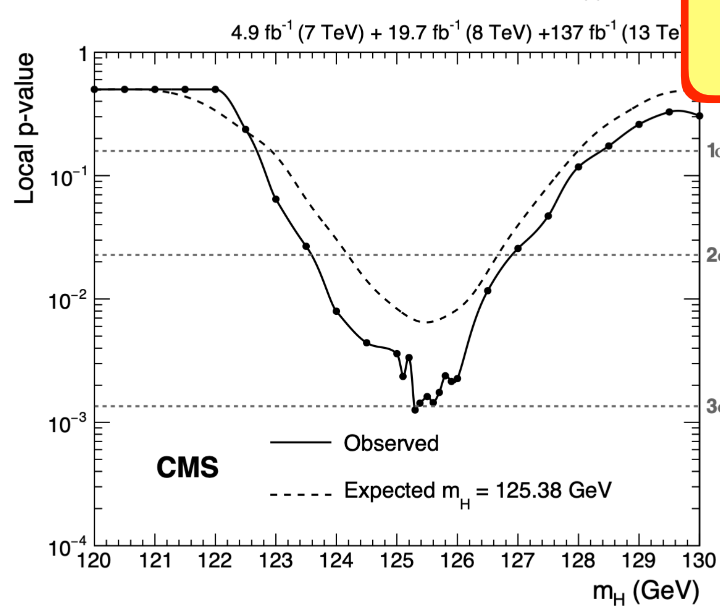

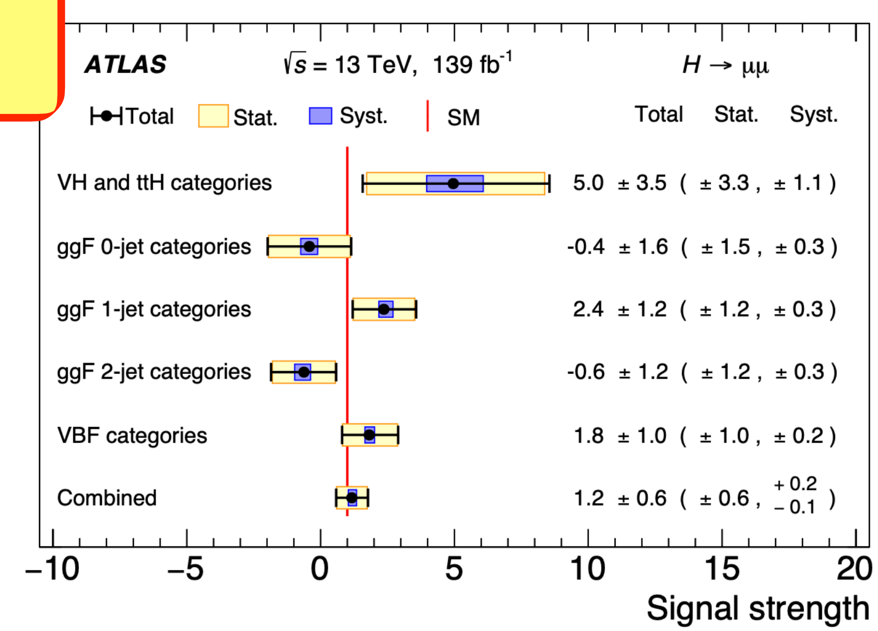

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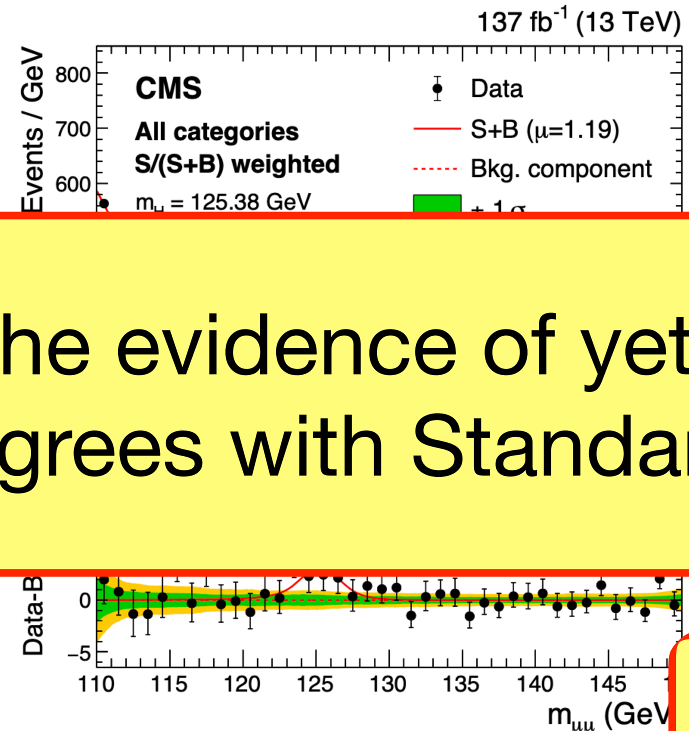

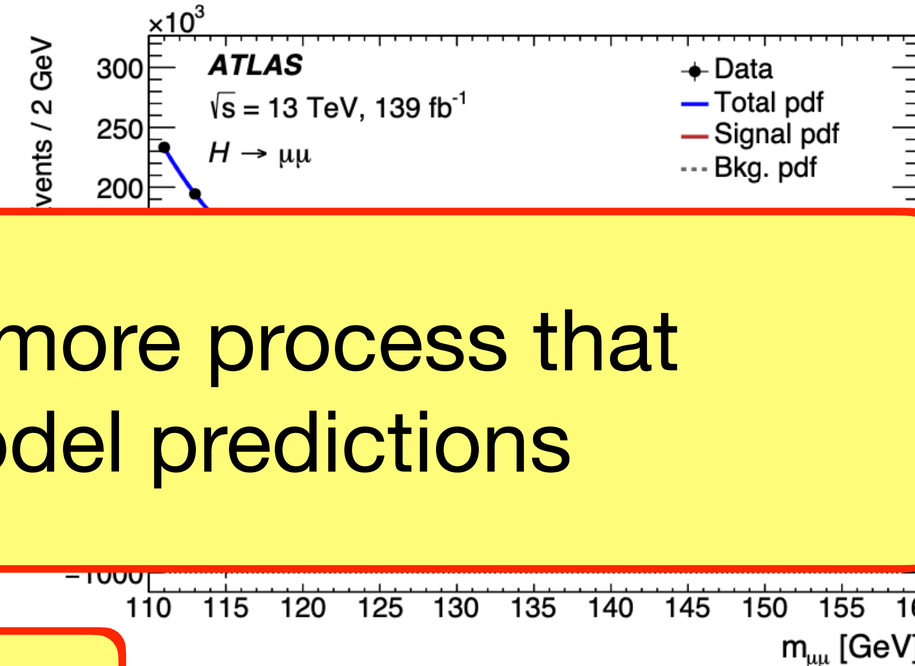

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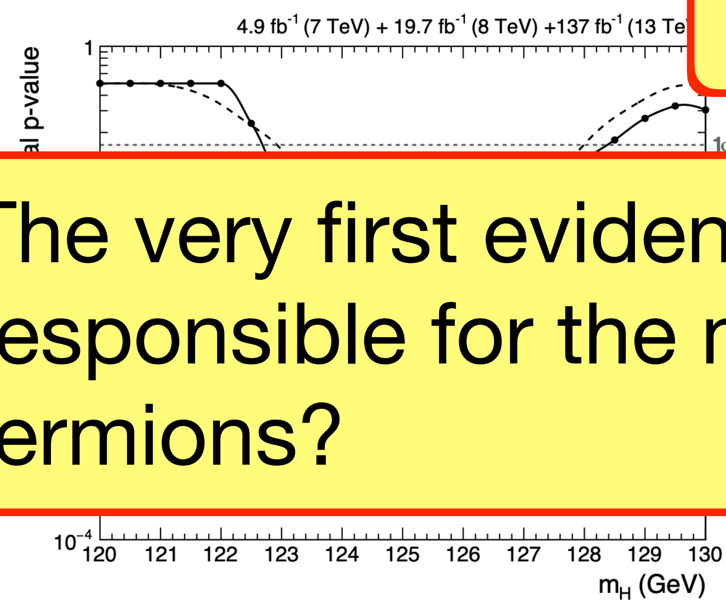
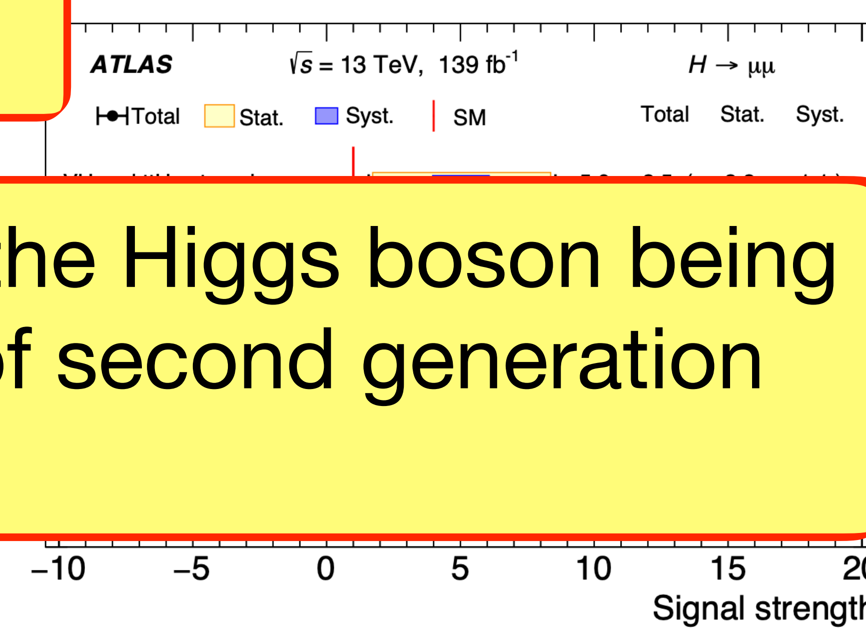




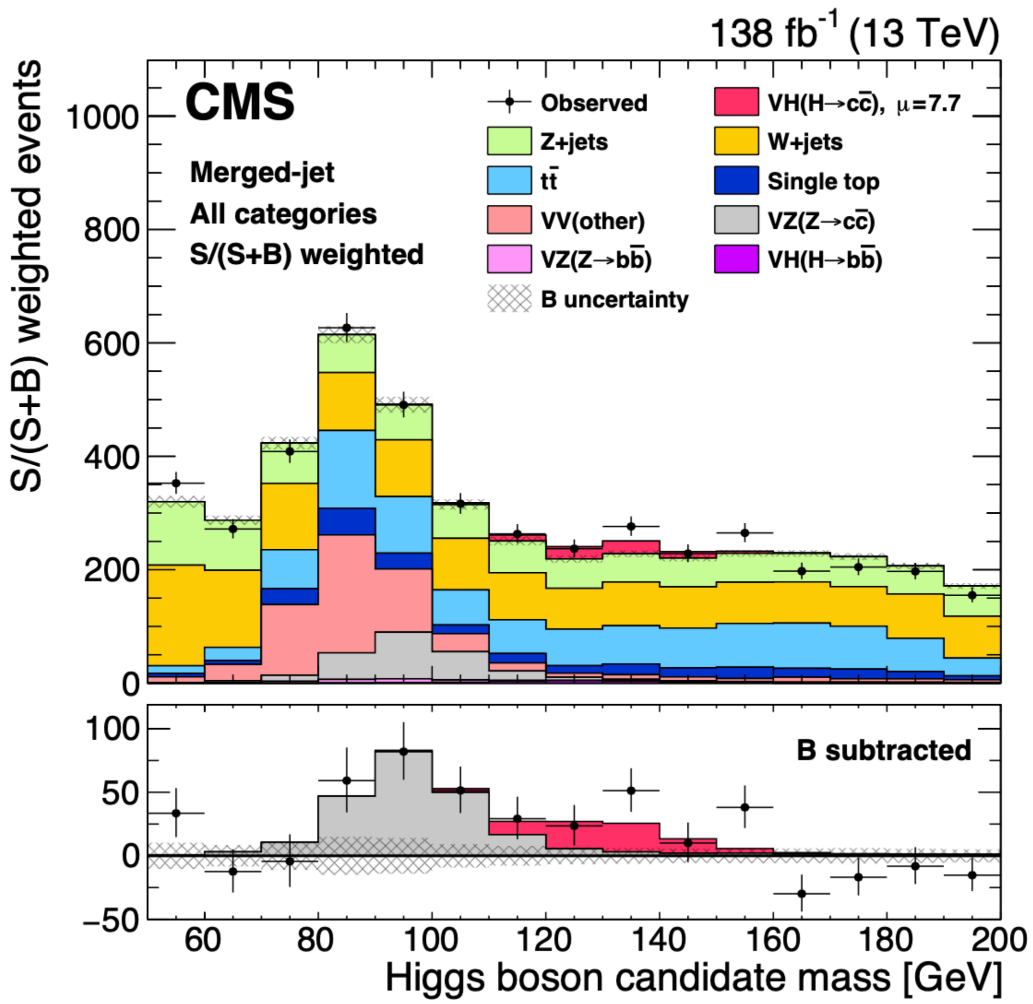
The very first evidence of the Higgs boson being responsible for the mass of second generation fermions?

CMS, 2205.05550

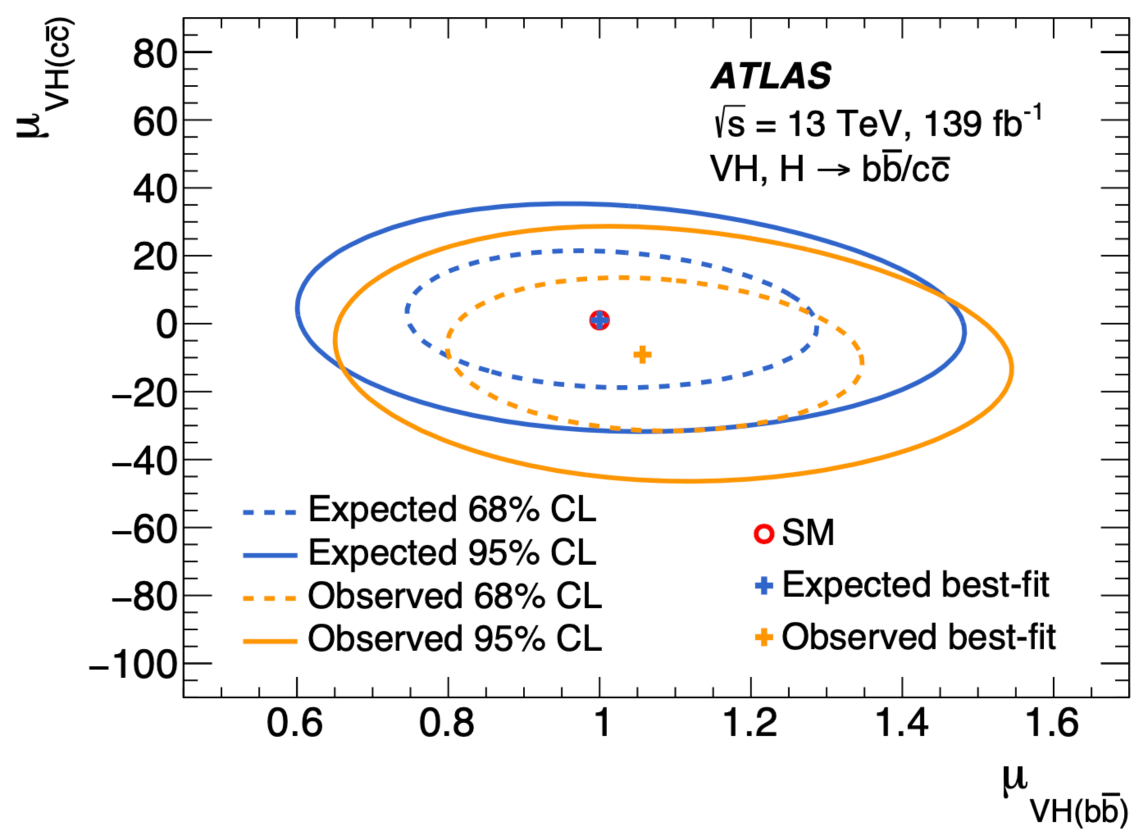
ATLAS, 2007.07830

Role of precision theory predictions rather limited

Recent highlights: H→cc



$1.1 < |\kappa_c| < 5.5\ (|\kappa_c| < 3.4)$



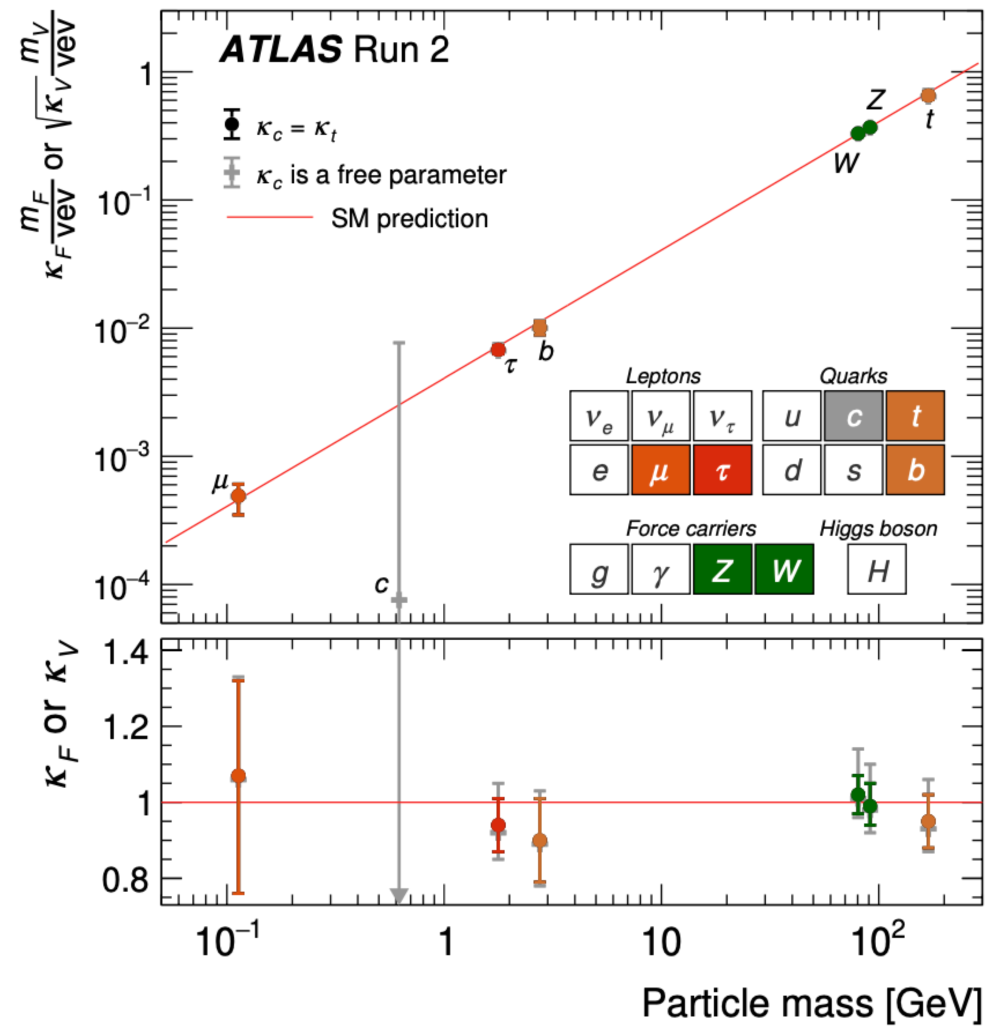
ATLAS, 2201.11428

CMS, 2205.05550

Crucial role of precision theory predictions for the prediction and simulation of background processes

Footprint of the SM Higgs

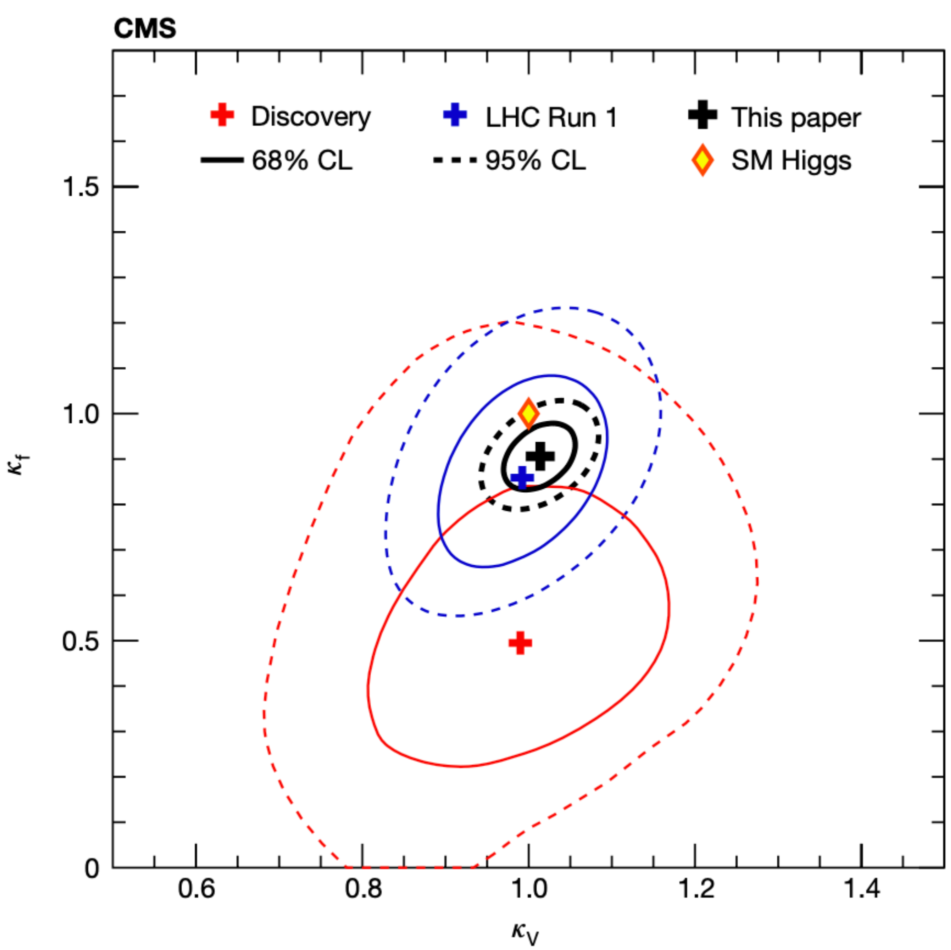
ATLAS *Nature* 607 (2022) 7917



So far, the Higgs behaves SM like, as far as couplings to third and second generation are concerned.
Still large room for BSM effects in couplings to 1st and 2nd generation

Higgs couplings to fermions and bosons

CMS *Nature* 607 (2022) 7917



"Global" fermion and vector coupling modifiers can be used to quantify the LHC capability to constrain BSM effects

Very many ways of constraining BSM effects in Higgs physics using SMEFT, including using non-Higgs related observables and vice-versa

⇒ see e.g. talks of R. Franceschini, D. Marzocca, E. Vryonidou, A. Martin, G. Piaquadio

Higgs and New Physics

Seeds of New Physics in the Higgs Lagrangian:

$$\mathcal{L}(\phi) = (D_\mu \phi)^\dagger (D^\mu \phi) - \mu_0^2 |\phi|^2 + \lambda |\phi|^4 + Y_{ij} \bar{\psi}_L^i \psi_R^j \phi$$

Gauge invariant mass generation of gauge bosons in the SM

The Higgs mass terms. Connected to the naturalness problem

The Higgs quartic self-interaction. Connected to the question of the stability of the potential

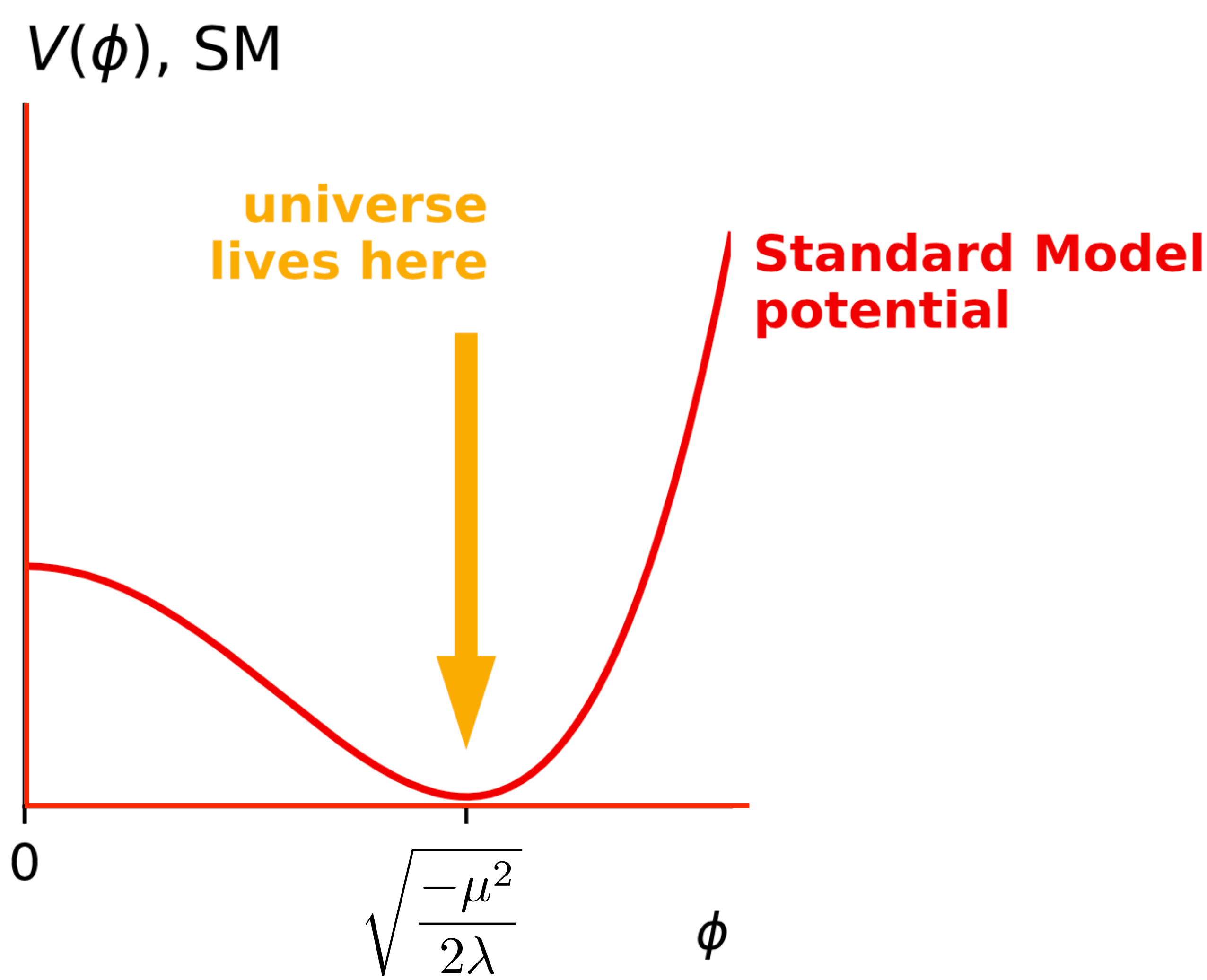
Yukawas give mass to fermions. Connected to flavour/CP problem

The Higgs potential

$$V(\phi) = \mu^2|\phi|^2 + \lambda|\phi|^4$$

Theorist's assumption

the cornerstone of the SM, also connects with the stability of the universe

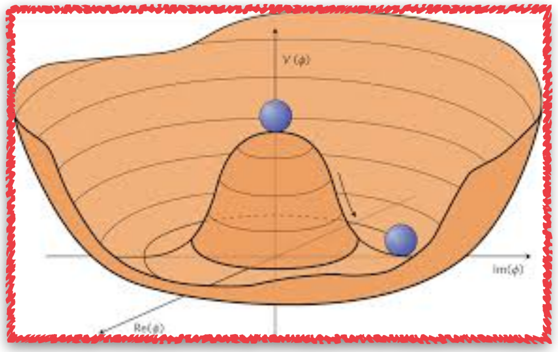


The Higgs boson is responsible for the masses of all particles. Its potential, linked to the Higgs self-coupling, is predicted in the SM, but we have not tested it so far

Establishing this assumption is a big answerable question, a guaranteed pay-off

The Higgs potential

After electroweak symmetry breaking:



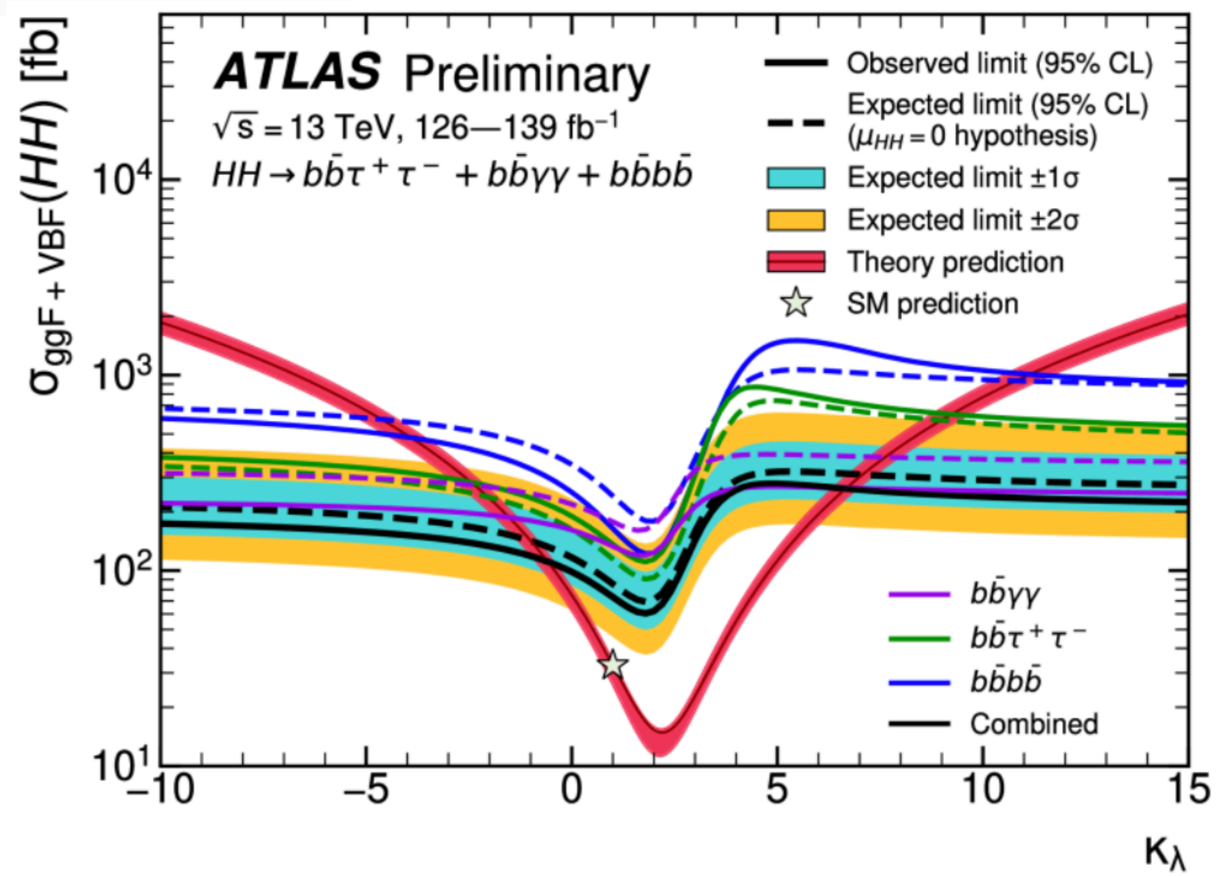
$$V_{\rm SM} = \boxed{\frac{m_h}{2}h^2} + \boxed{\lambda v h^3} + \boxed{\frac{\lambda}{4}h^4}$$

- [x] Single Higgs
  done
  O(7 millions)
- [ ] Double Higgs
  very hard
  O(7000)
- [ ] Triple Higgs
  out of reach
  O(15)

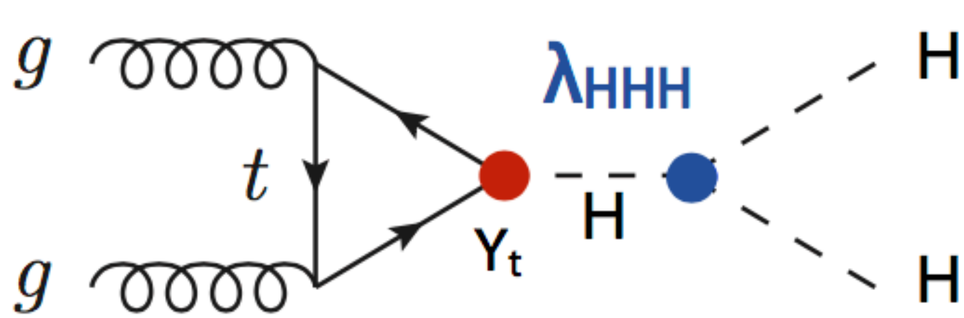
events produced so far

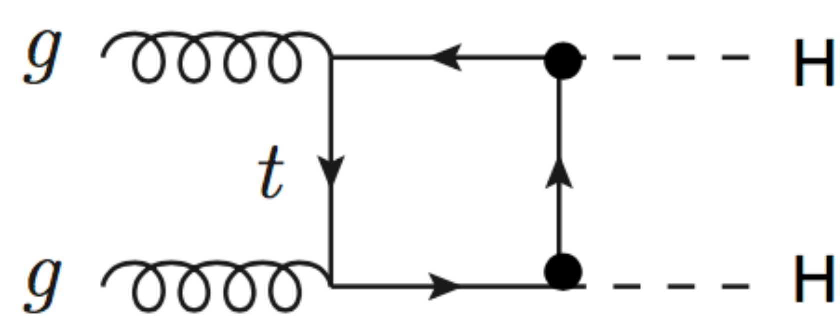
The Higgs self-coupling

- Double-Higgs production is directly sensitive to the self-coupling
- Sensitivity limited also because of destructive interference



ATLAS-CONF-2022-050 (see also 2211.01216)



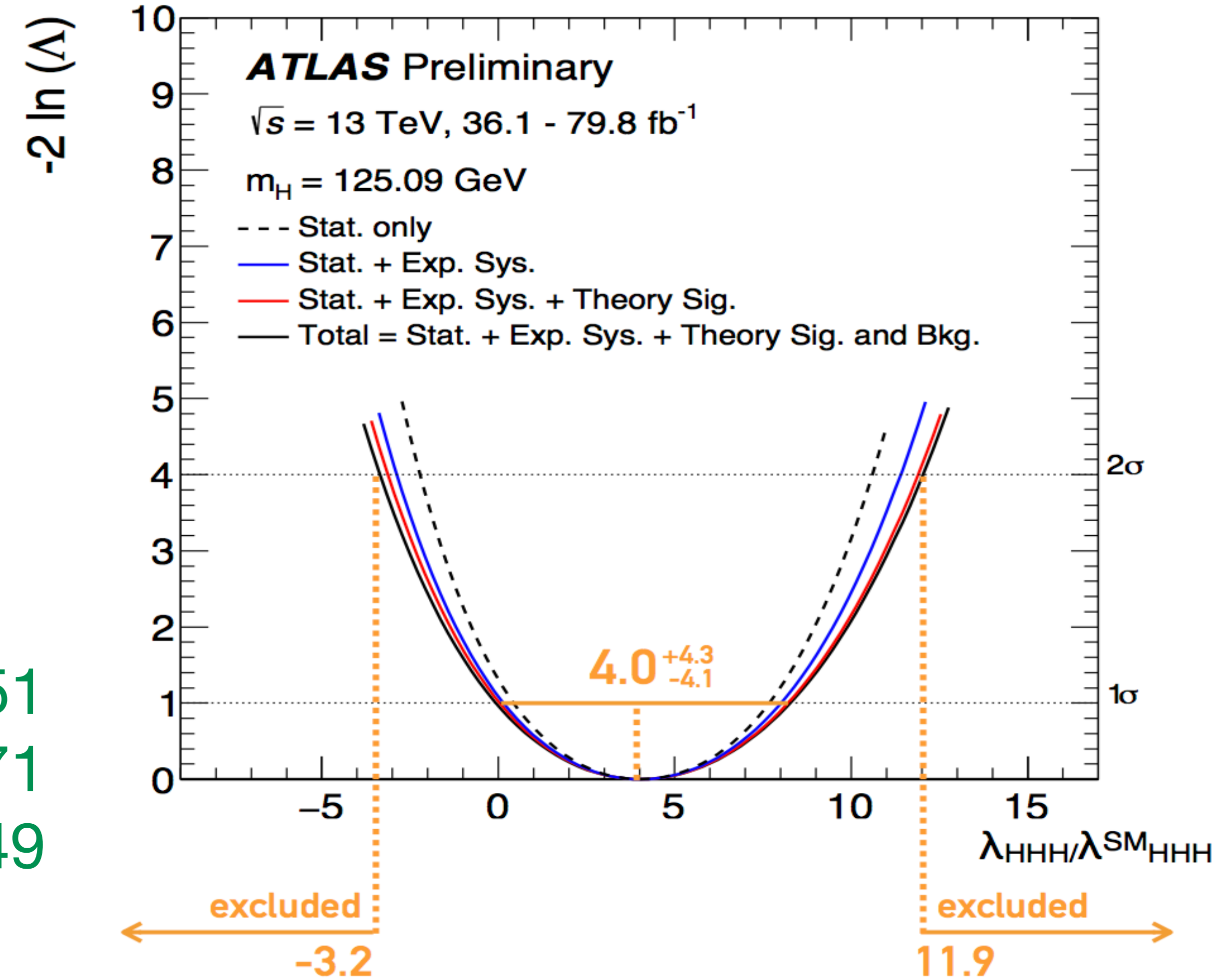


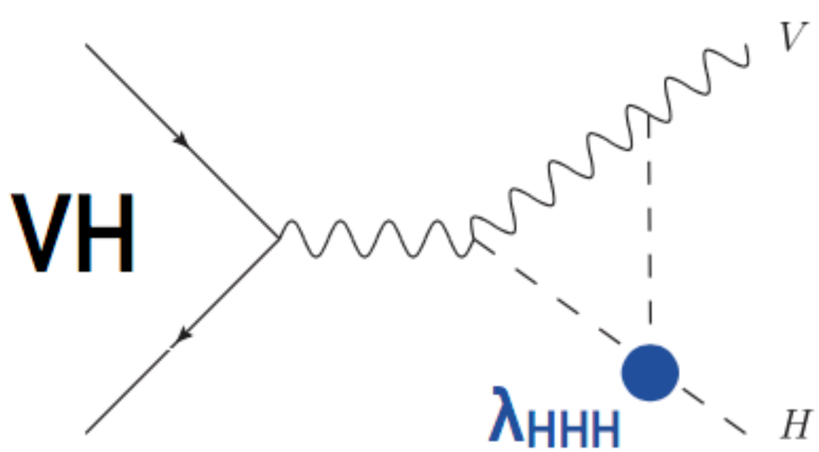
⇒ see e.g. talks of L. Skyboz, N. De Filippi …

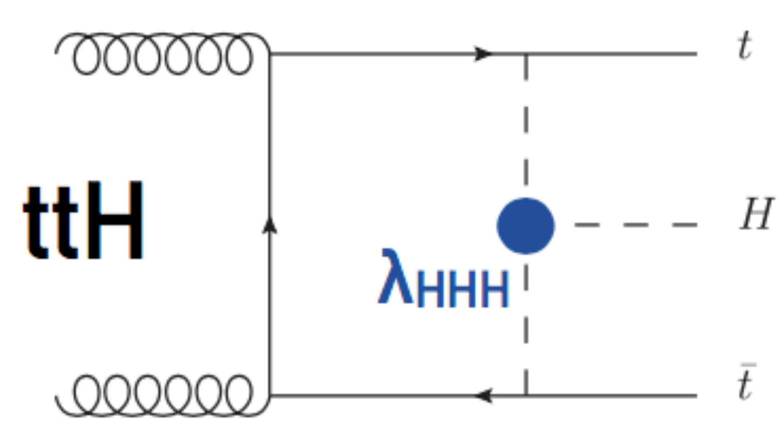
The Higgs self-coupling

- Single-Higgs production modes indirectly sensitive to the self-coupling through electro-weak effects
- Precision theory predictions absolutely crucial

De Grassi et al 1607.04251
Bizon et al 1610.05771
Maltoni et al 1709.08649

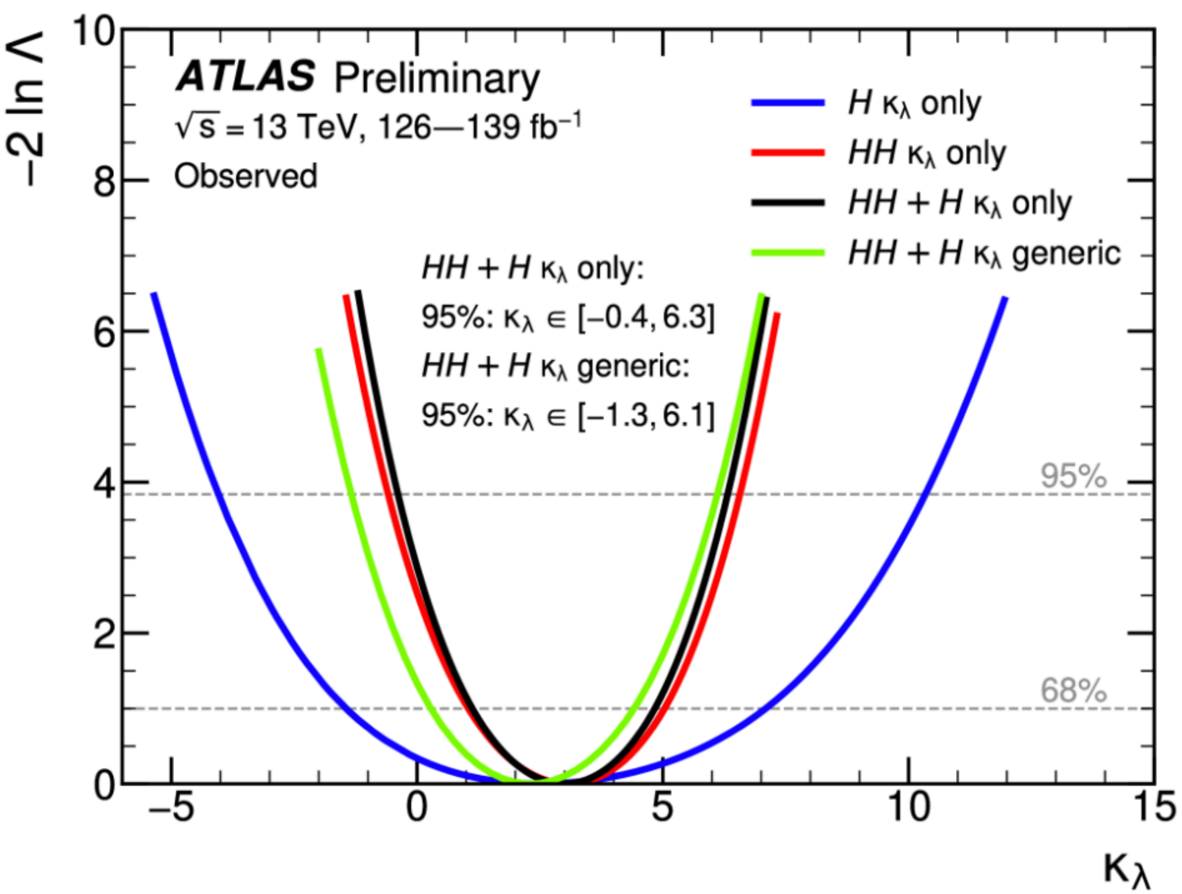






H+HH combination

ATLAS-CONF-2022-050 (see also 2211.01216)



⇒ no relevant gain from single-Higgs

H+HH combination

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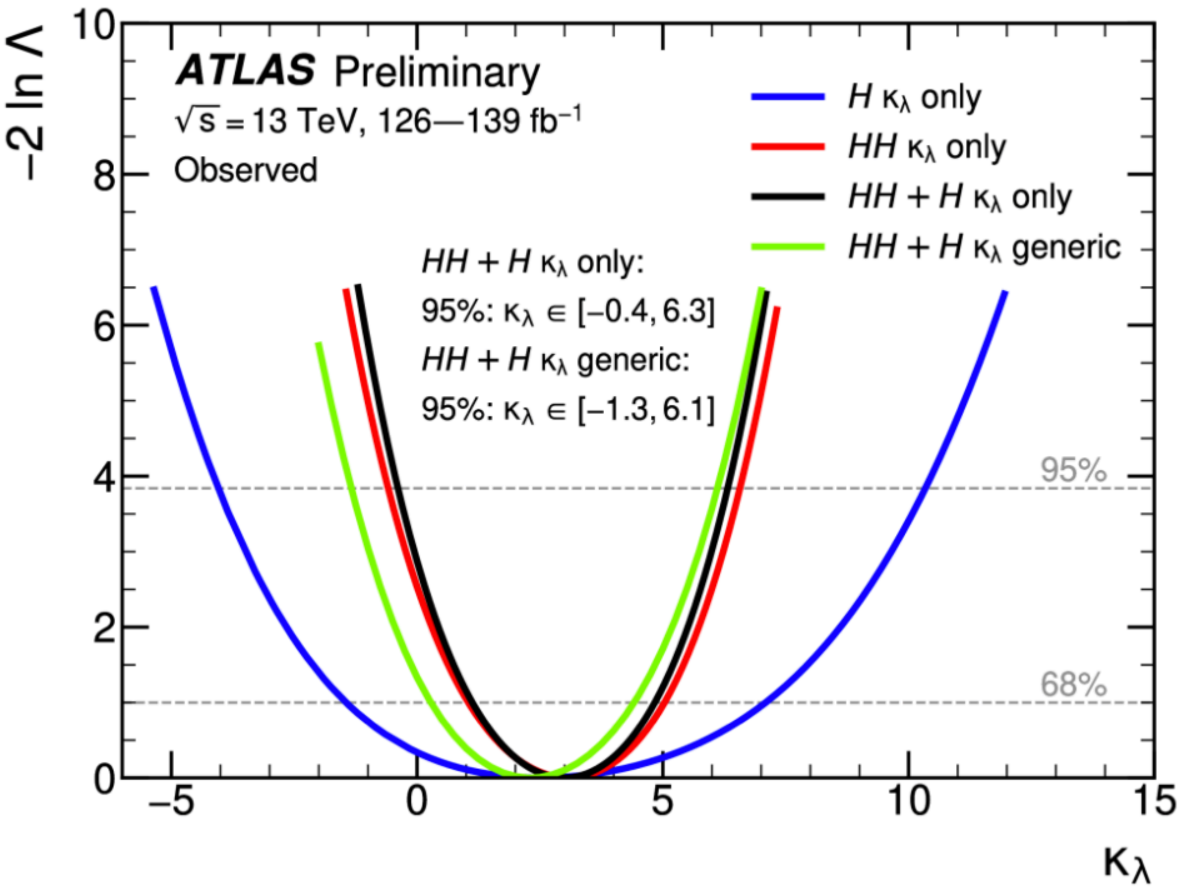
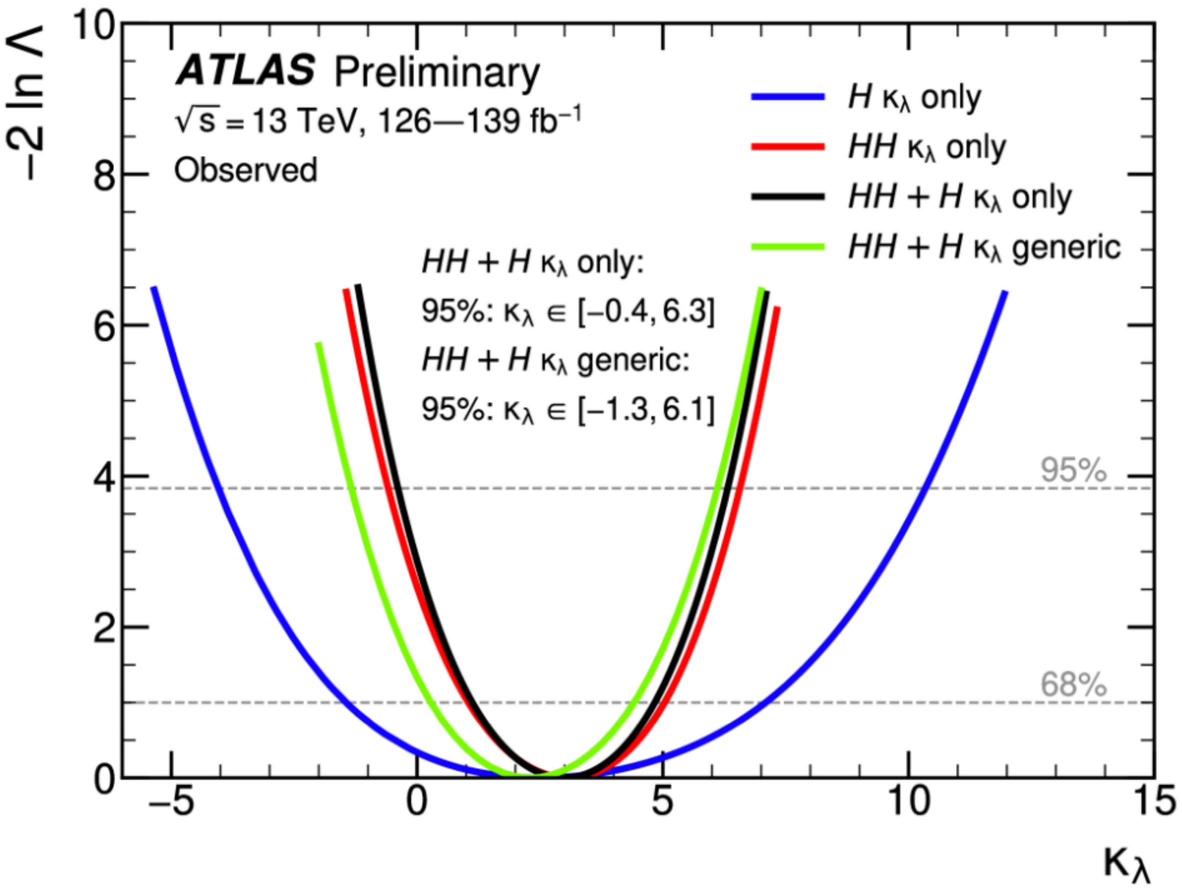


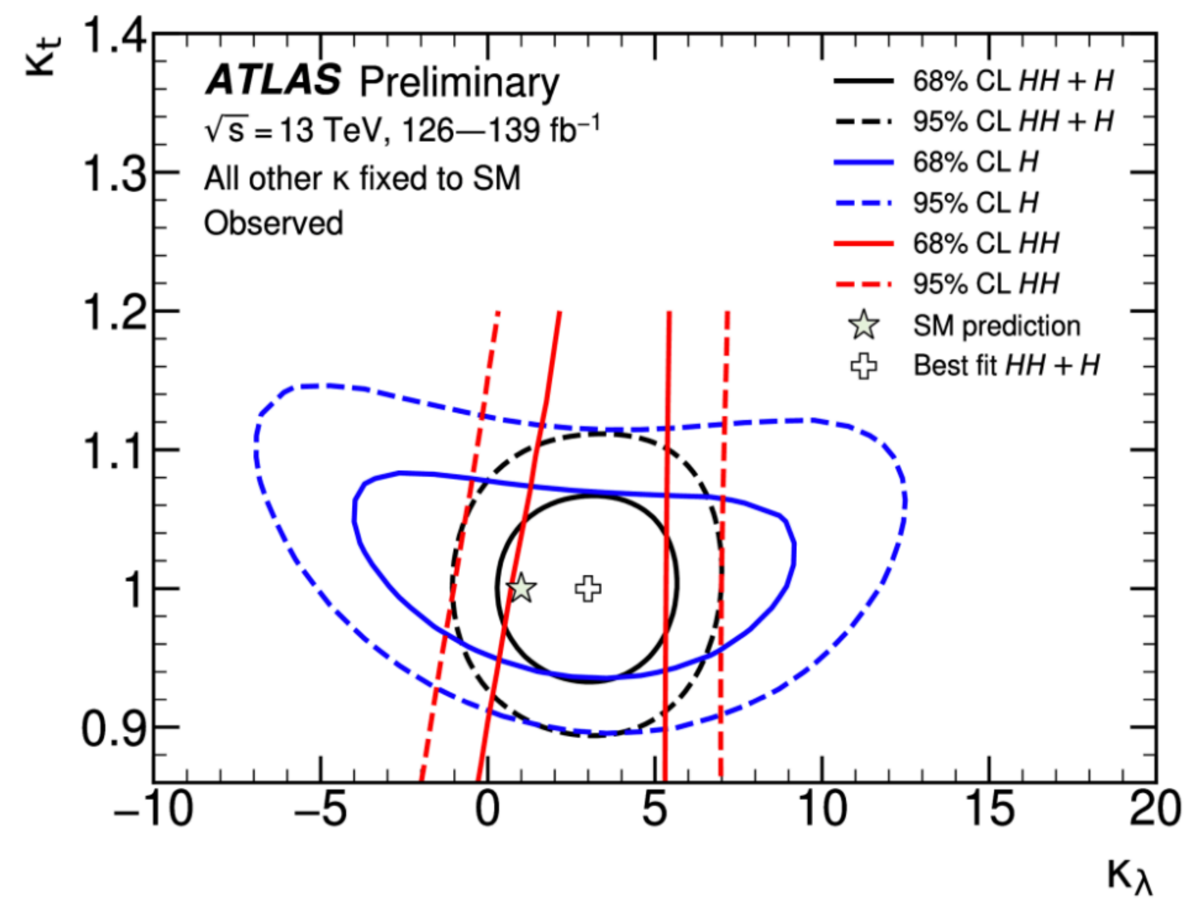
⇒ no relevant gain from single-Higgs

BUT

H+HH combination

ATLAS-CONF-2022-050 (see also 2211.01216)





⇒ no relevant gain from single-Higgs

BUT

⇒ the combination of H and HH allows to constrain κ_λ and other "κ" (e.g. κ_t)

10 years of Higgs in the media

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Il bosone di Higgs scoperto 10 anni fa: come la caccia alla «particella di Dio» ha cambiato la nostra visione del mondo

Dieci anni fa l'annuncio del primo «avvistamento» del bosone di Higgs confermò la sostanziale validità del Modello Standard, la teoria scientifica che cerca di spiegare il mondo. Ma schiuse anche le porte a nuovi e inesplorati campi di ricerca

How the boson changed our understanding of the world

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Dieci anni dopo la scoperta del bosone di Higgs: quello che sappiamo finora

Infodata | 9 Luglio 2022

Oggi si celebrano i 10 anni dalla scoperta del bosone di Higgs: era infatti il **4 luglio del 2012** quando **veniva annunciata in diretta mondiale** alla conferenza ICHEP – International Conference on High Energy Physics in corso a Melbourne la scoperta di una nuova particella, grazie alle collaborazioni internazionali degli esperimenti ATLAS e CMS all'acceleratore LHC Large Hadron Collider del CERN di Ginevra.

What we know so far

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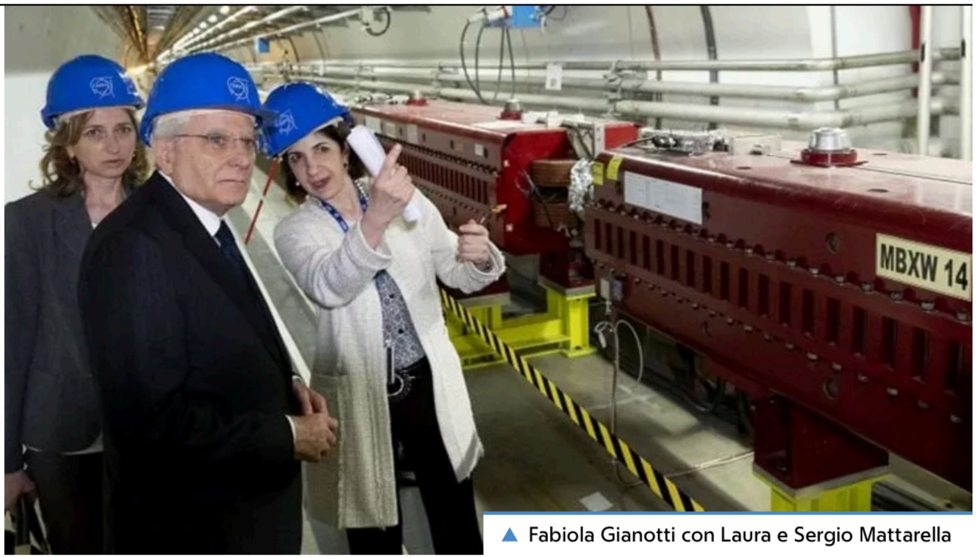
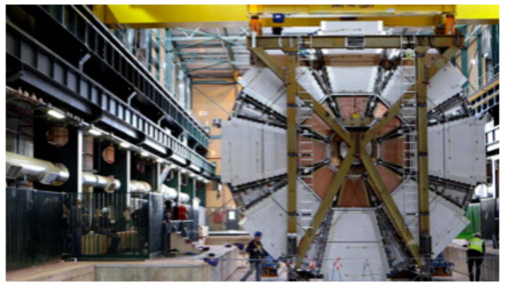
Fabiola Gianotti: "Dieci anni dopo il bosone resta il mistero dell'universo"

di Elena Dusi



Fabiola Gianotti con Laura e Sergio Mattarella

After 10 years, the Higgs remains the biggest mystery



Physik

Zehn Jahre Higgs-Boson: Was der Teilchenphysik noch bleibt

What remains to particle physics after ten years

3. Juli 2022, 8:56 Uhr / Quelle: dpa /

Higgs-Boson

Higgs, sonst nix

Higgs, otherwise nothing

Die Teilchenphysik kommt einfach nicht vom Fleck. Und feiert unterdessen Jubiläum

Ein Kommentar von **Stefan Schmitt**

Aktualisiert am 11. Juli 2022, 7:58 Uhr / 37 Kommentare /

AUS DER
ZEIT NR. 28/2022

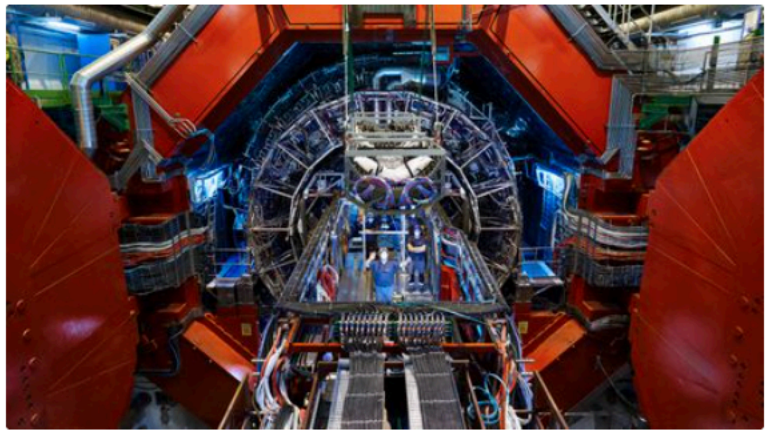
The most expensive crash in the world

Europäisches Forschungszentrum Cern

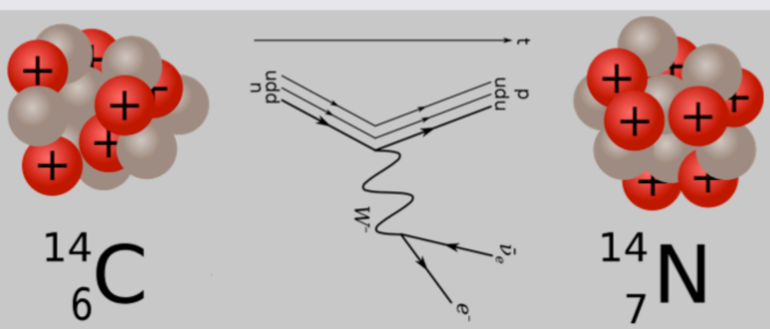
S+ Der teuerste Crashtest der Welt

Die Physiker am Teilchenbeschleuniger LHC lassen es nach drei Jahren Pause wieder krachen. Wenn ihnen kein Durchbruch gelingt, rechnen Experten mit dem Aus eines ganzen Forschungsfeldes. Von Johann Grolle

11. Juli 2022, 00.15 Uhr • 11 Min



Higgs and everyday life

role of fundamental particle masses	consequence in daily life	Higgs role established?
Up quarks (mass ~ 2.2 MeV) lighter than down quarks (~ 4.7 MeV) **proton** (up+up+down): 2.2 + **2.2** + 4.7 + EM+strong force = **938.3** MeV **neutron** (up+down+down): 2.2 + **4.7** + 4.7 + EM+strong force = **939.6** MeV	up & down-quark masses mean protons are **lighter** than neutrons, → protons are stable, giving us hydrogen	
 atomic radius $\propto \frac{1}{m_e}$	Electron mass (m_e) sets size of atoms & energy levels of chemical reactions	
 *decay rate* $\propto \frac{1}{m_W^4}$	W-boson mass (m_W) sets rate of radioactive β-decay	

Why do Higgs interactions matter to everyone?
Within the Standard Model of particle physics, they set quark, electron & W masses, with important consequences

Adapted from Salam, Wang, GZ *Nature* 607 (2022) 7917

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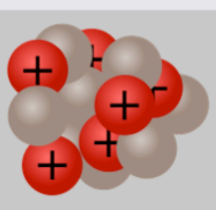
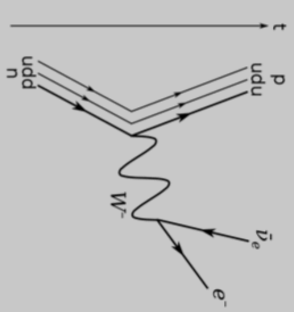
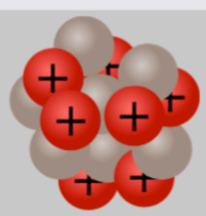
 $^{14}_{6}C$   $^{14}_{7}N$ *decay rate* $\propto \frac{1}{m_W^4}$	W-boson mass (m_W) sets rate of radioactive β-decay	

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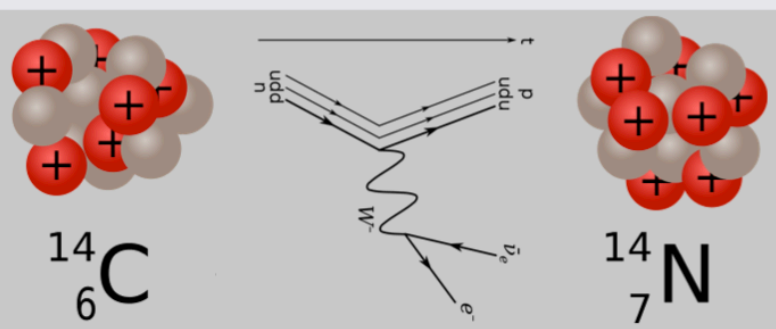 *decay rate* $\propto \frac{1}{m_W^4}$	W-boson mass (m_W) sets rate of radioactive β-decay	

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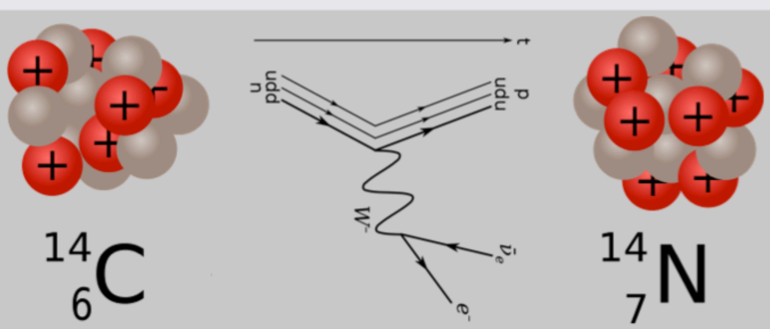 $^{14}_{6}$C → $^{14}_{7}$N *decay rate* $\propto \frac{1}{m_W^4}$	W-boson mass (m_W) sets rate of radioactive β-decay	**YES**

Why do Higgs interactions matter to everyone?

Within the Standard Model of particle physics, they set quark, electron & W masses, with important consequences

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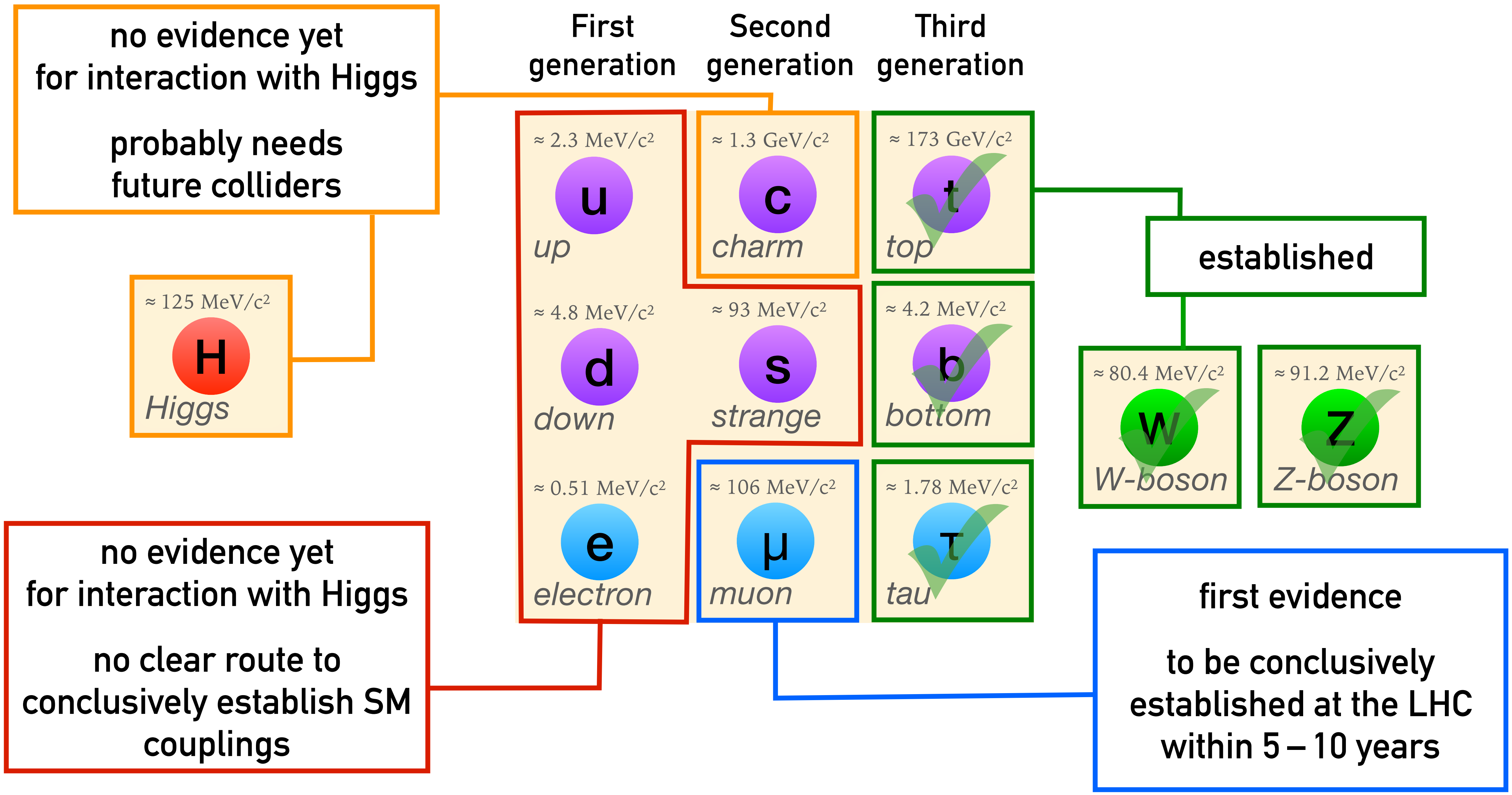
Higgs interactions

Status and prospects of our knowledge of Higgs interactions with known particles



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Possible connections of the Higgs to major open questions

What is the origin of the early-universe inflation?

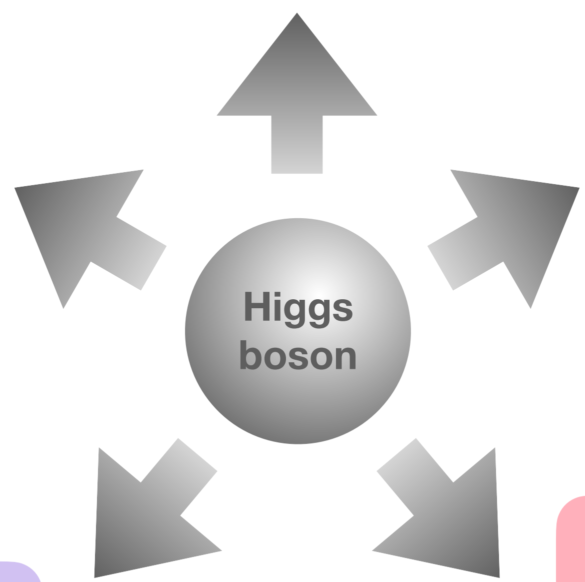
- Is the Higgs connected to the mechanism that drives inflation?
- Are there any imprints in cosmological observations?

Why is the electroweak interaction so much stronger than gravity?

- Are there new particles close to the mass of the Higgs boson?
- Is the Higgs boson elementary or made of other particles?
- Are there anomalies in the interactions of the Higgs with the W and Z?

What is the origin of the vast range of quark and lepton masses in the Standard Model?

- Are there modified interactions to the Higgs boson and known particles?
- Does the Higgs decay into pairs of quarks and leptons with distinct flavours (for example, $H \rightarrow \mu^{+}\tau^{-}$)?



What is dark matter?

- Can the Higgs provide a portal to dark matter or a dark sector?
- Is the Higgs lifetime consistent with the Standard Model?
- Are there new decay modes of the Higgs?

Why is there more matter than antimatter in the universe?

- Are there charge-parity violating Higgs decays?
- Are there anomalies in the Higgs self-coupling that would imply a strong first-order early-universe electroweak phase transition?
- Are there multiple Higgs sectors?

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Conclusions

- The discovery of the Higgs boson marked a milestone in particle physics
- In ten years the Higgs has been portrait to remarkable precision, yet many crucial aspects still largely unconstraint (coupling to “ordinary matter”, Higgs potential, …)
- The scalar sector is connected to profound questions (naturalness, vacuum stability, flavour)
- Ten years after the Higgs discovery, the field of particle physics is blooming with new theoretical and experimental ideas on how to shed light on these profound mysteries

Conclusions

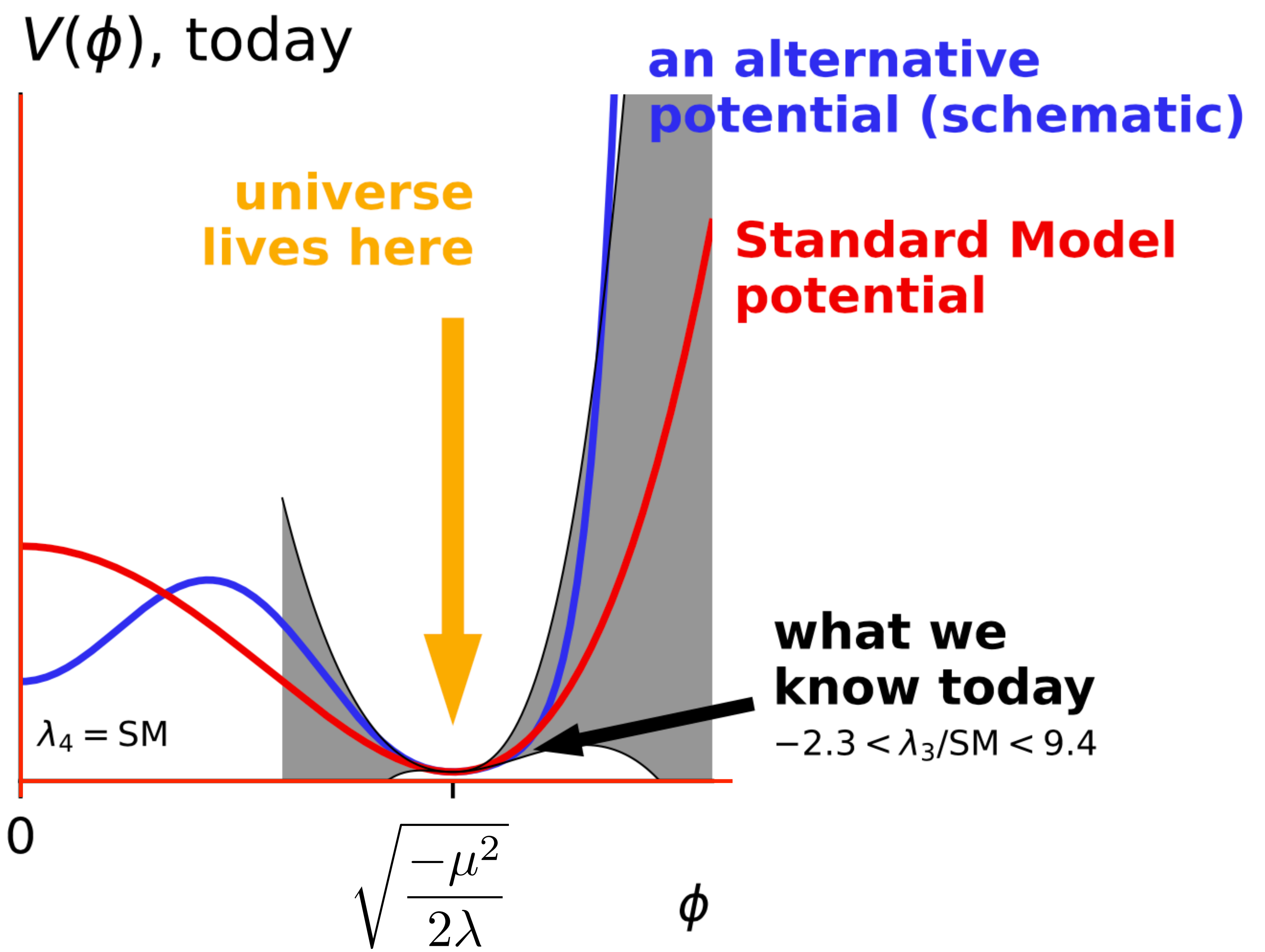
- The discovery allows us to explore a new sector with a broad experimental program that will extend over decades
  [in comparison the b-quark was discovered forty years ago and a new experiment, Belle II at SuperKEK, has recently started to further study hadrons containing b-quarks]
  ⇒ *see talks by P. Roloff and S. Dawson for exp. and theory prospects*

- Finding new physics would be amazing, but we should not allow dreams of New Physics to overshadow the crucial role of the LHC Higgs physics program
  (each experimental measurements adds up in a unique way to our understanding of the Higgs sector, and therefore of fundamental particle physics)

Backup

The Higgs potential

<u>What did we establish so far?</u>



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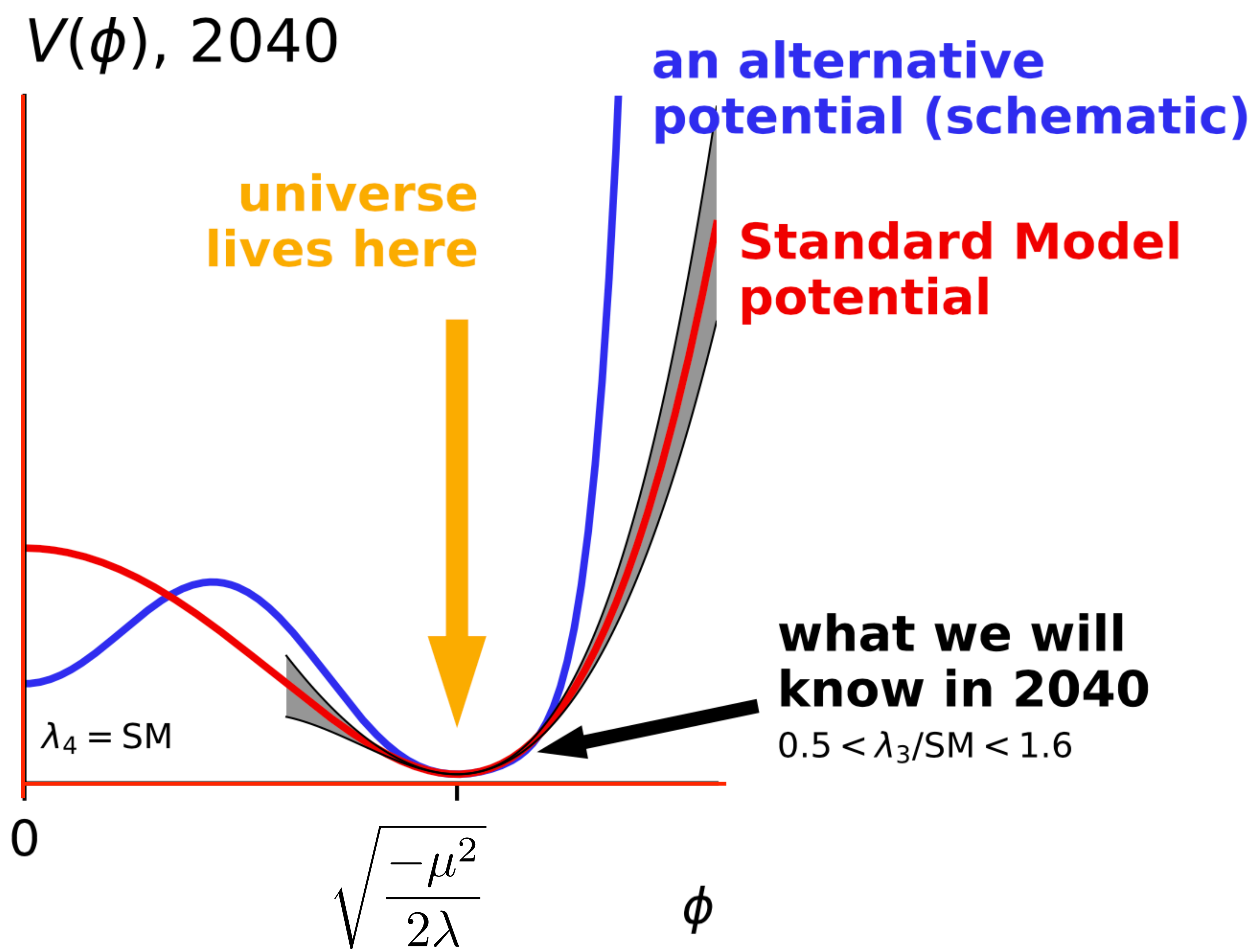
The Higgs potential

What are the prospects in the next twenty years?



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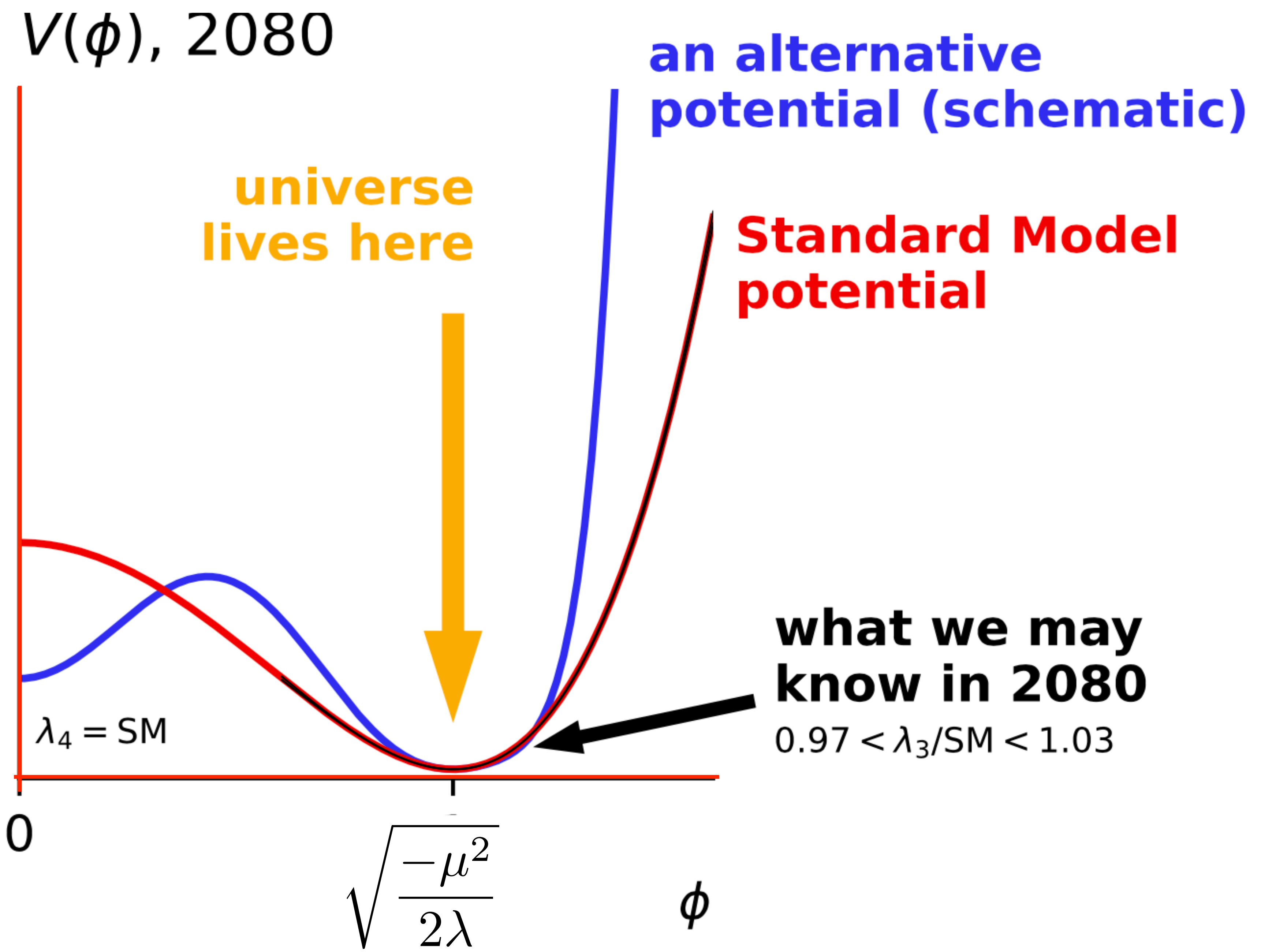
The Higgs potential

What are the prospects after a possible FCC ?



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