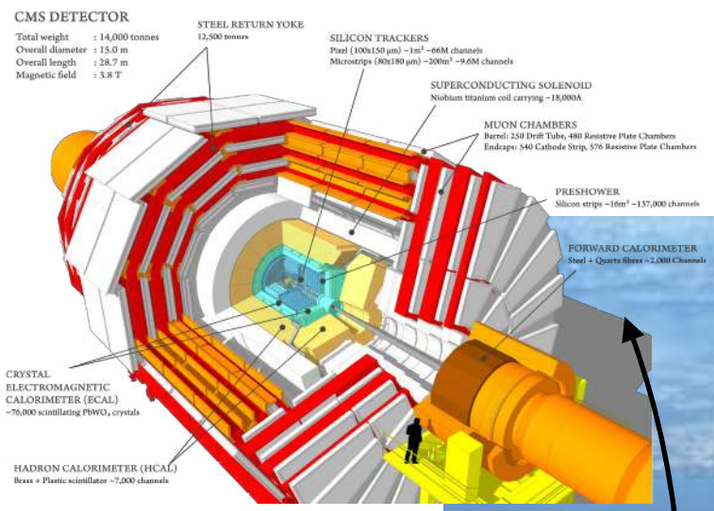
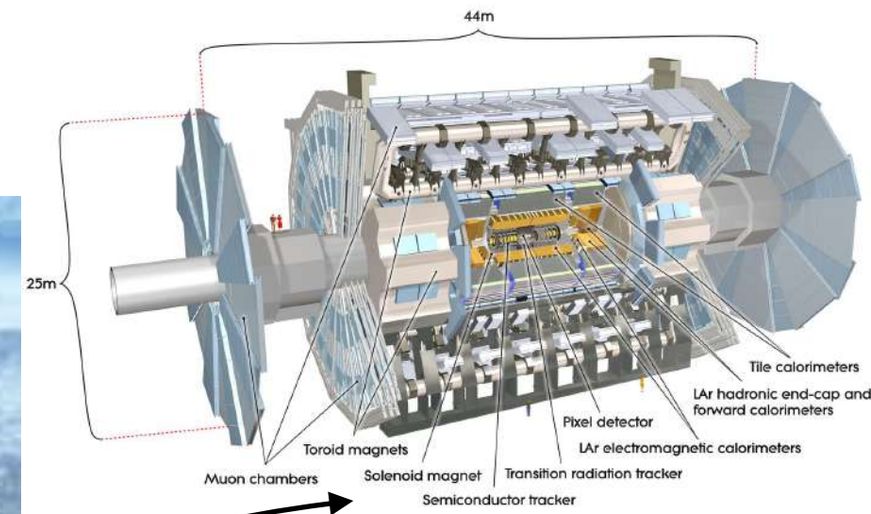
University of Zurich[UZH]

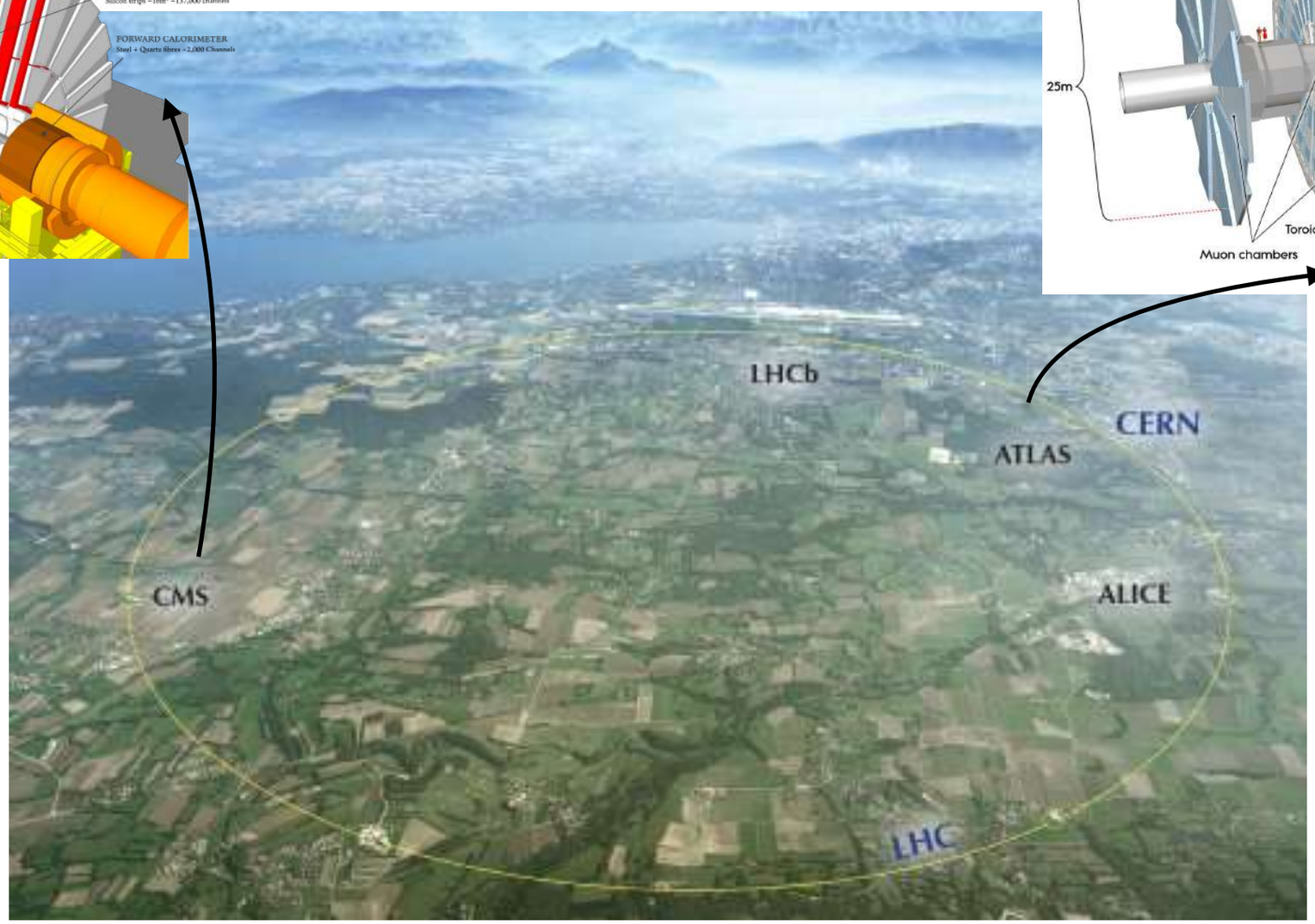
Higgs physics: the hunt for precision

A. de Wit, DIS2023, 27.03

CMS and ATLAS at the LHC



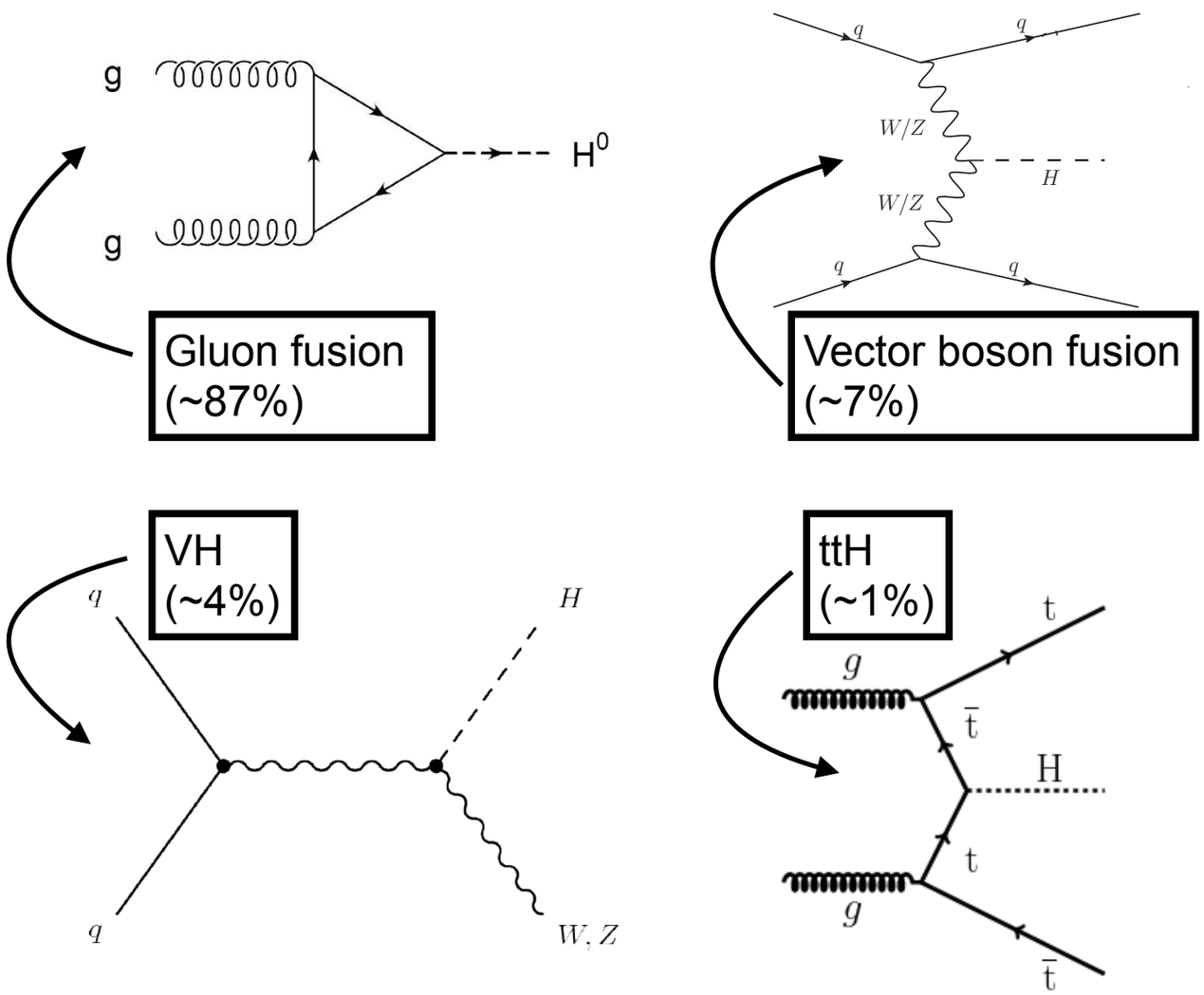




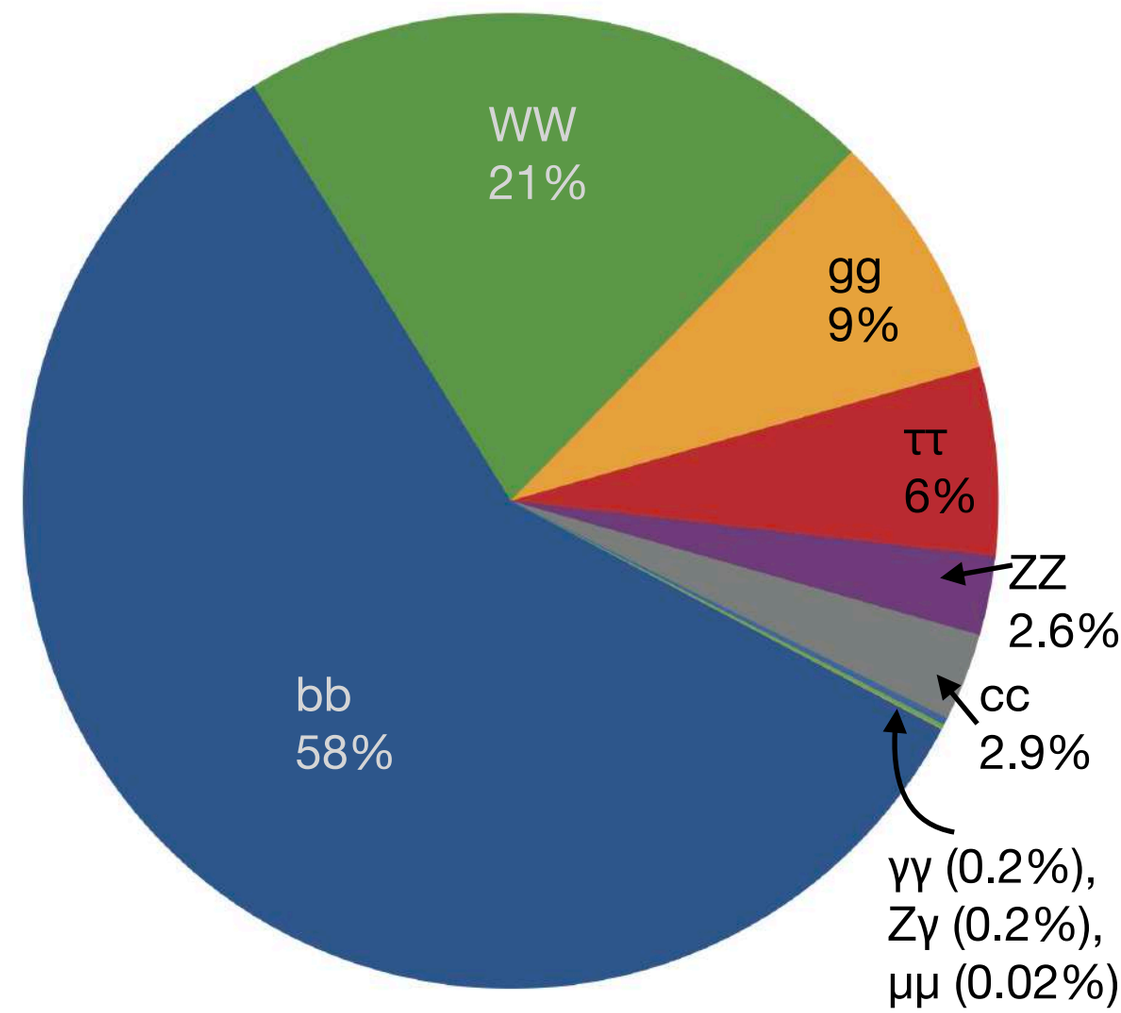
The Higgs boson at the LHC

- 10 years since the discovery of the Higgs boson
  - Many of the main production modes and decay channels firmly established experimentally
  - Ever more precise measurements of cross sections, properties

Production modes:



Decay channels:



Precision Higgs physics

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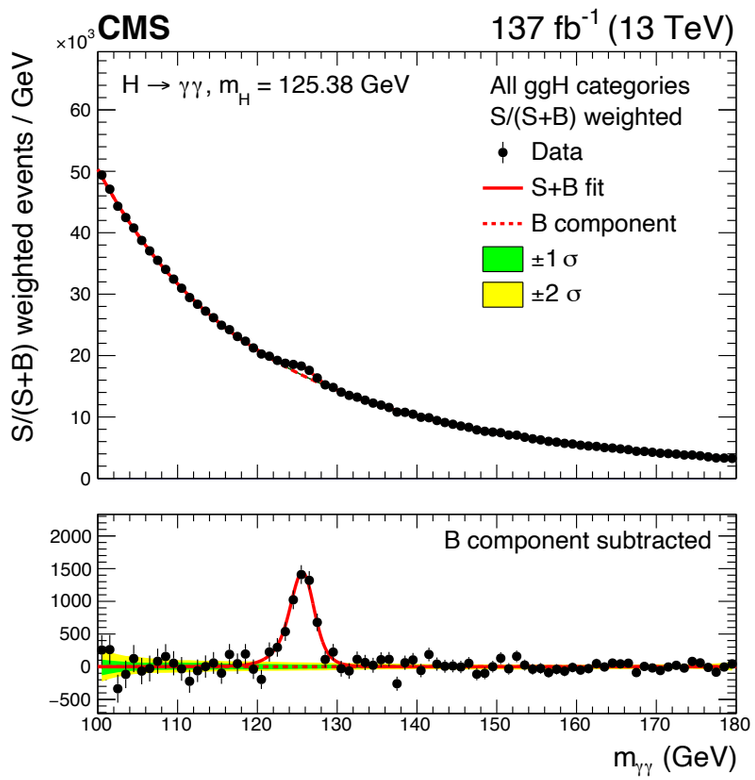

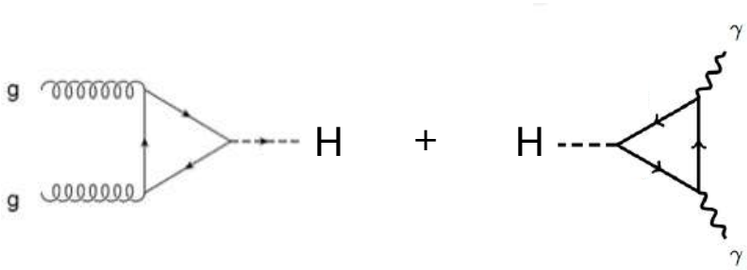

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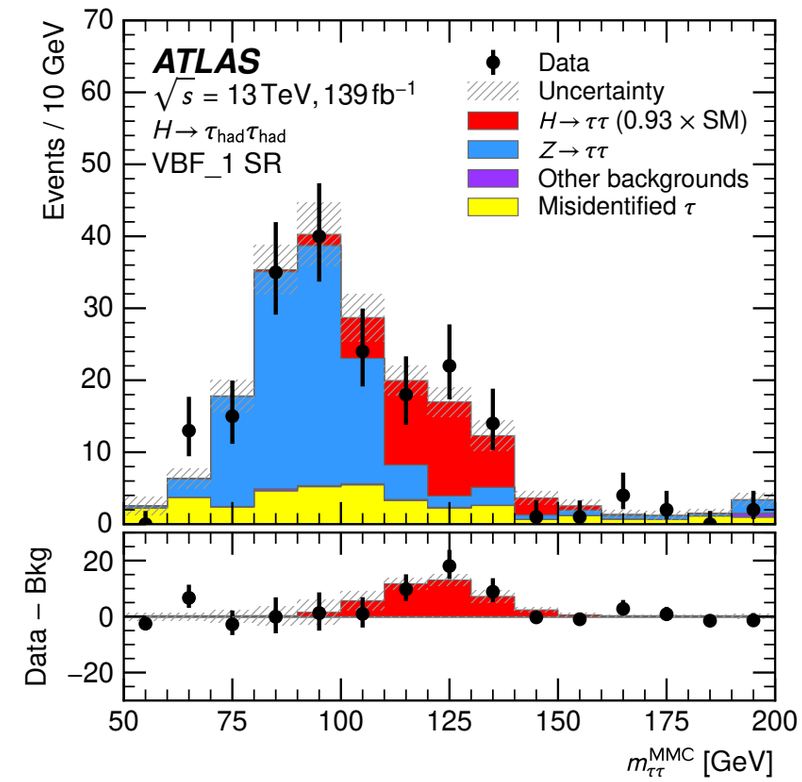

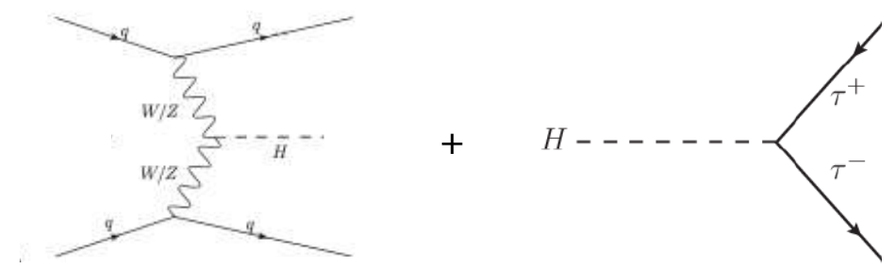

Precision Higgs physics

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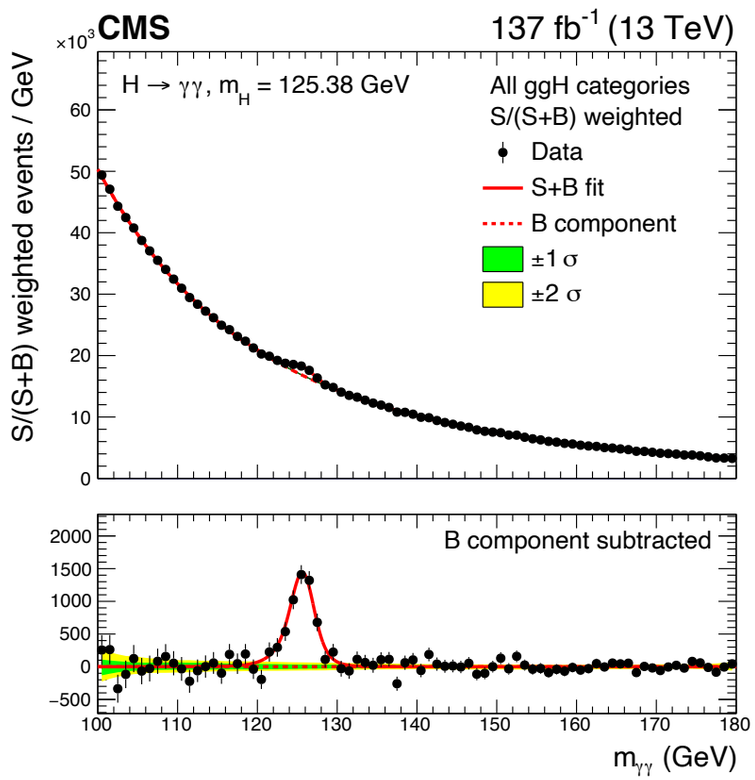

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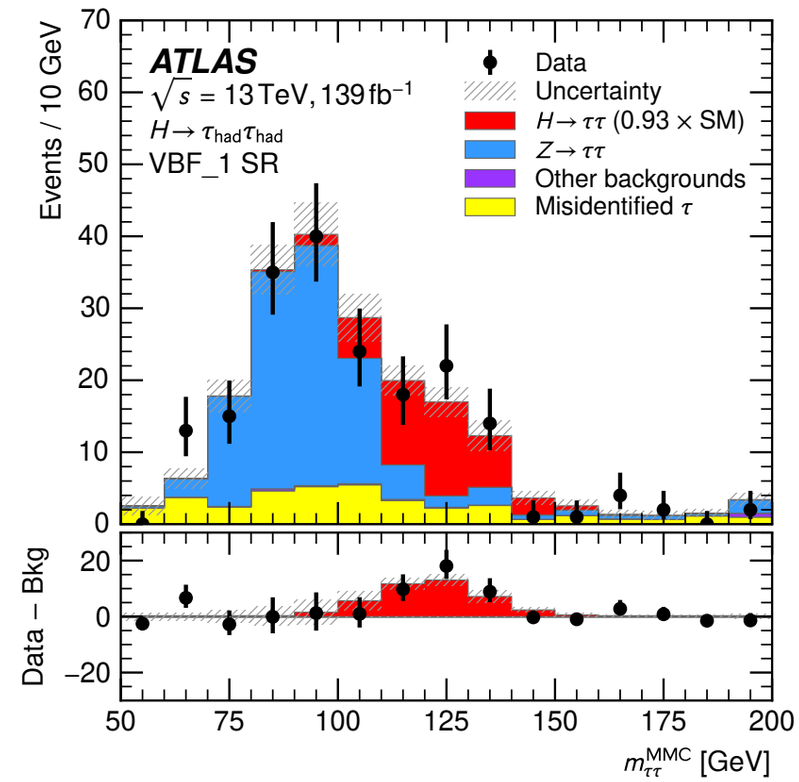

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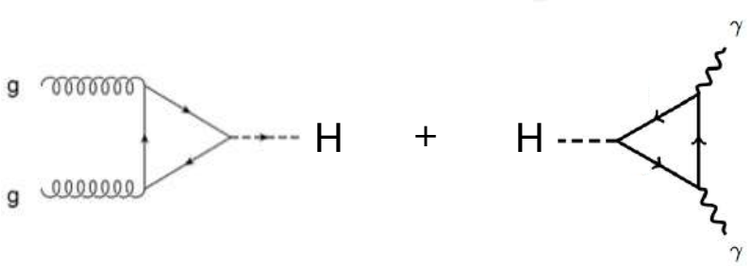

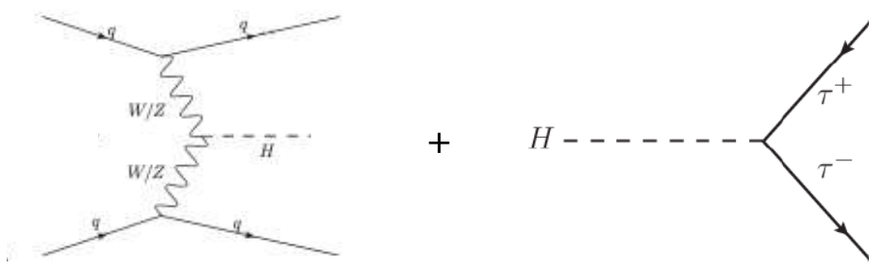

➔ To get a **full view of the Higgs boson**, need to **combine** individual analyses that study specific Higgs boson characteristics

➔ **Also leads to the best precision**

Higgs boson production and decay rates

σ_i

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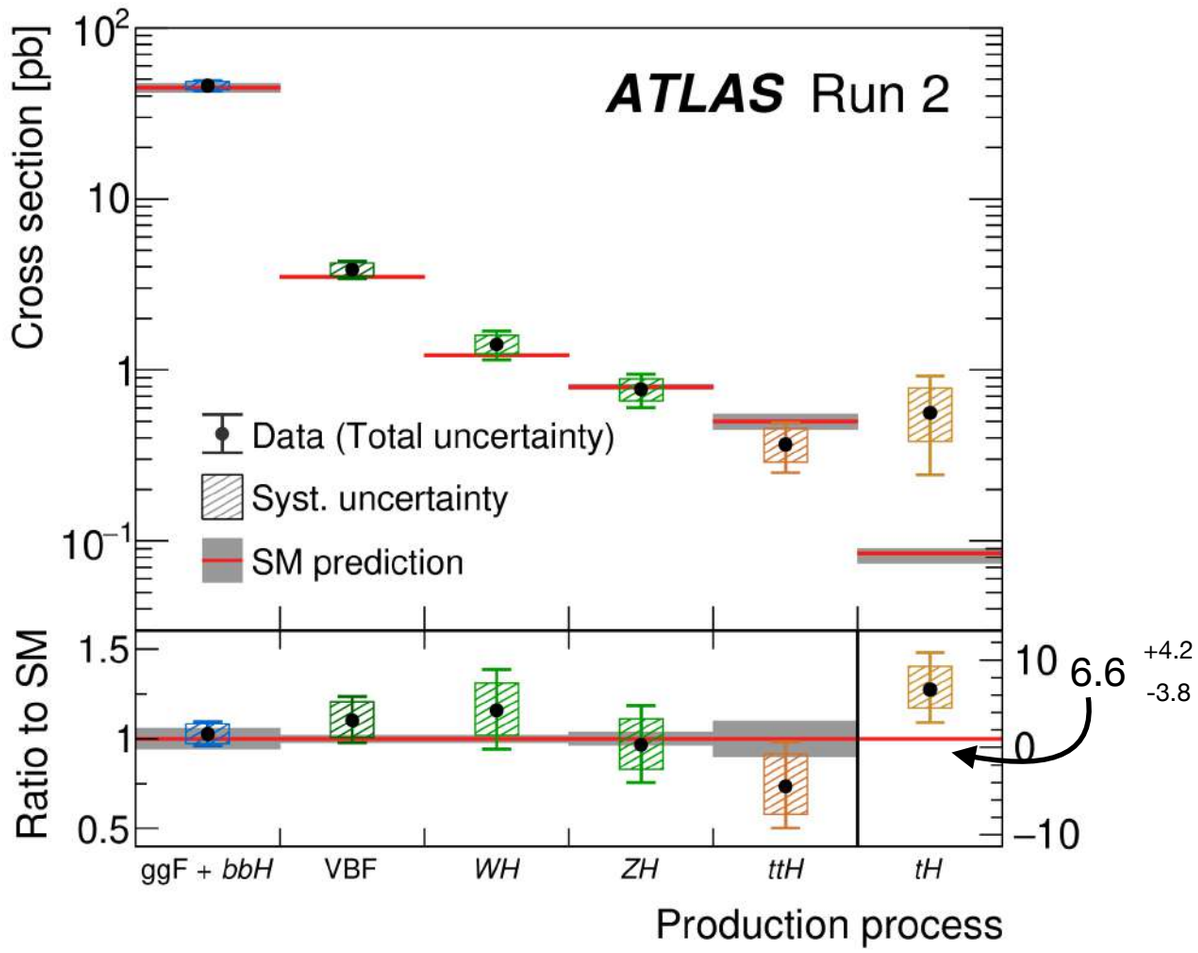


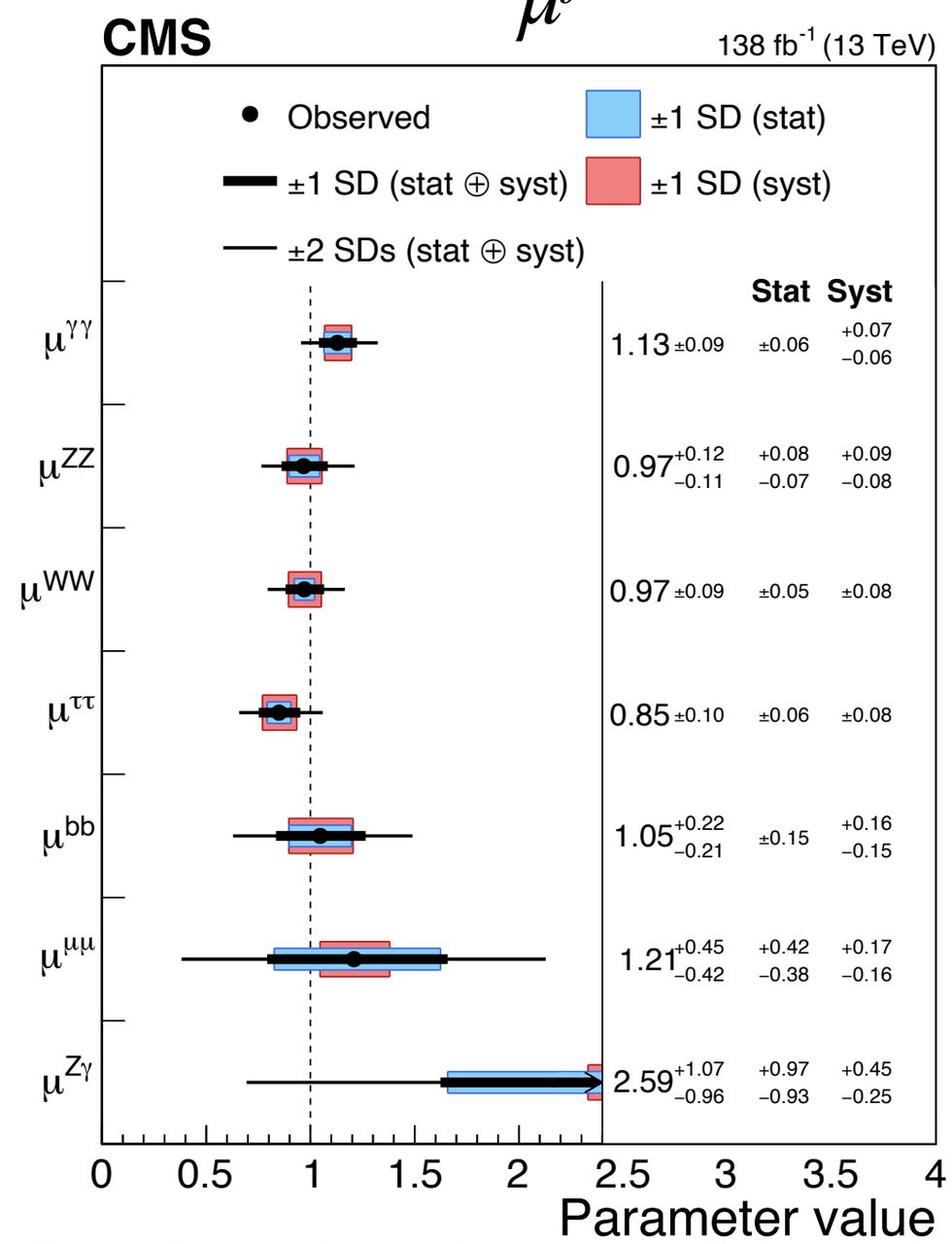
gluon-gluon fusion precision better than 10%!

10-20% precision on other major production modes

Measurement of σ_{tH} ➔ gaining access to rare production modes

μ^f

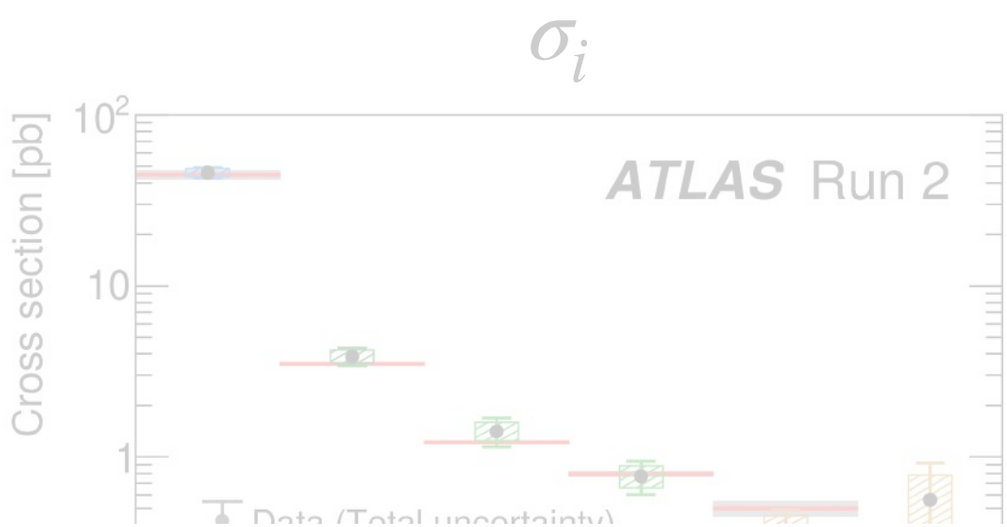
Nature 607 (2022) 60

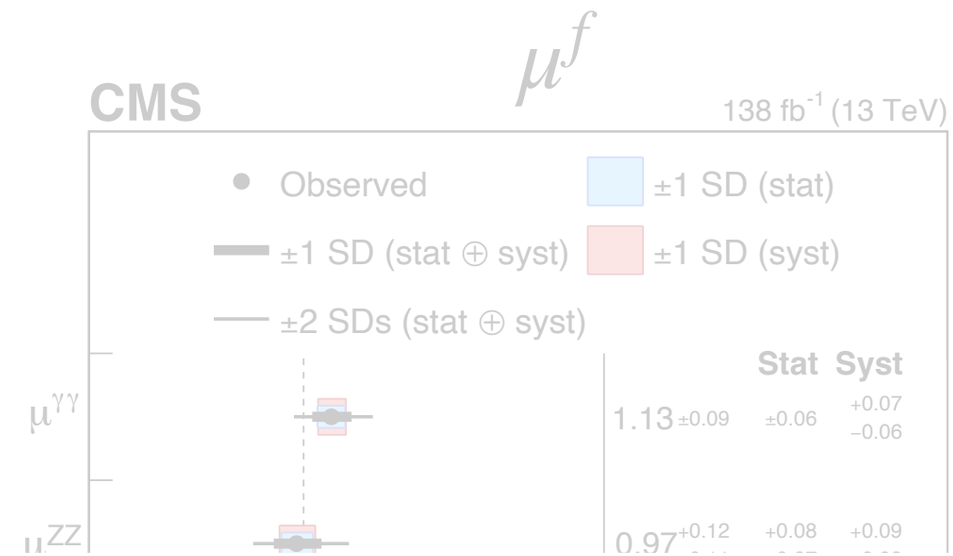


Precision on bosonic decays, decays to tau leptons: **~10%**

Uncertainties on rare decay branching fractions (μμ, Zγ) still sizeable

Higgs boson production and decay rates





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What does the Higgs boson have to do with this conference?

Measurement of σ_{tH} ➔ gaining access to rare production modes

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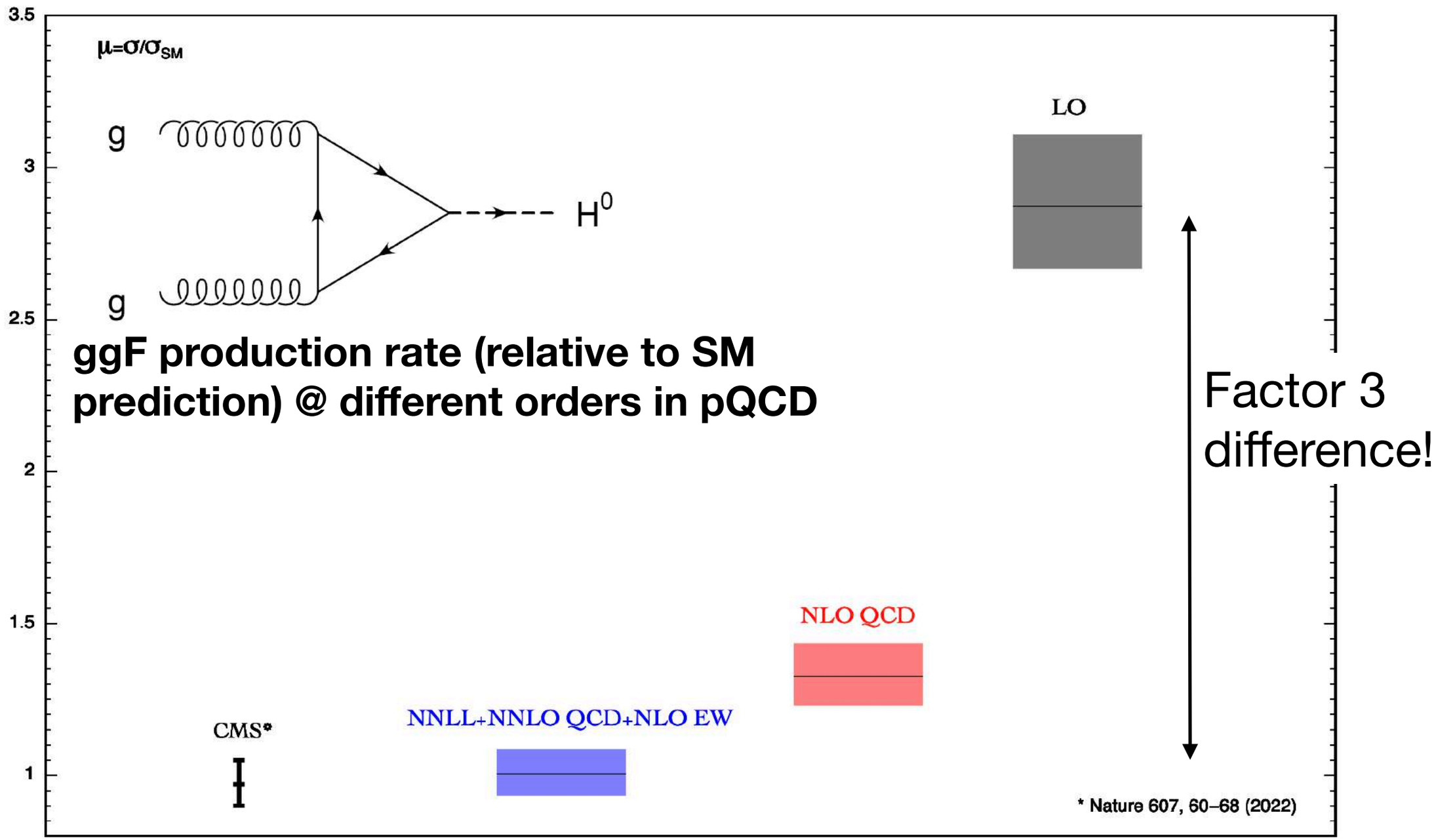
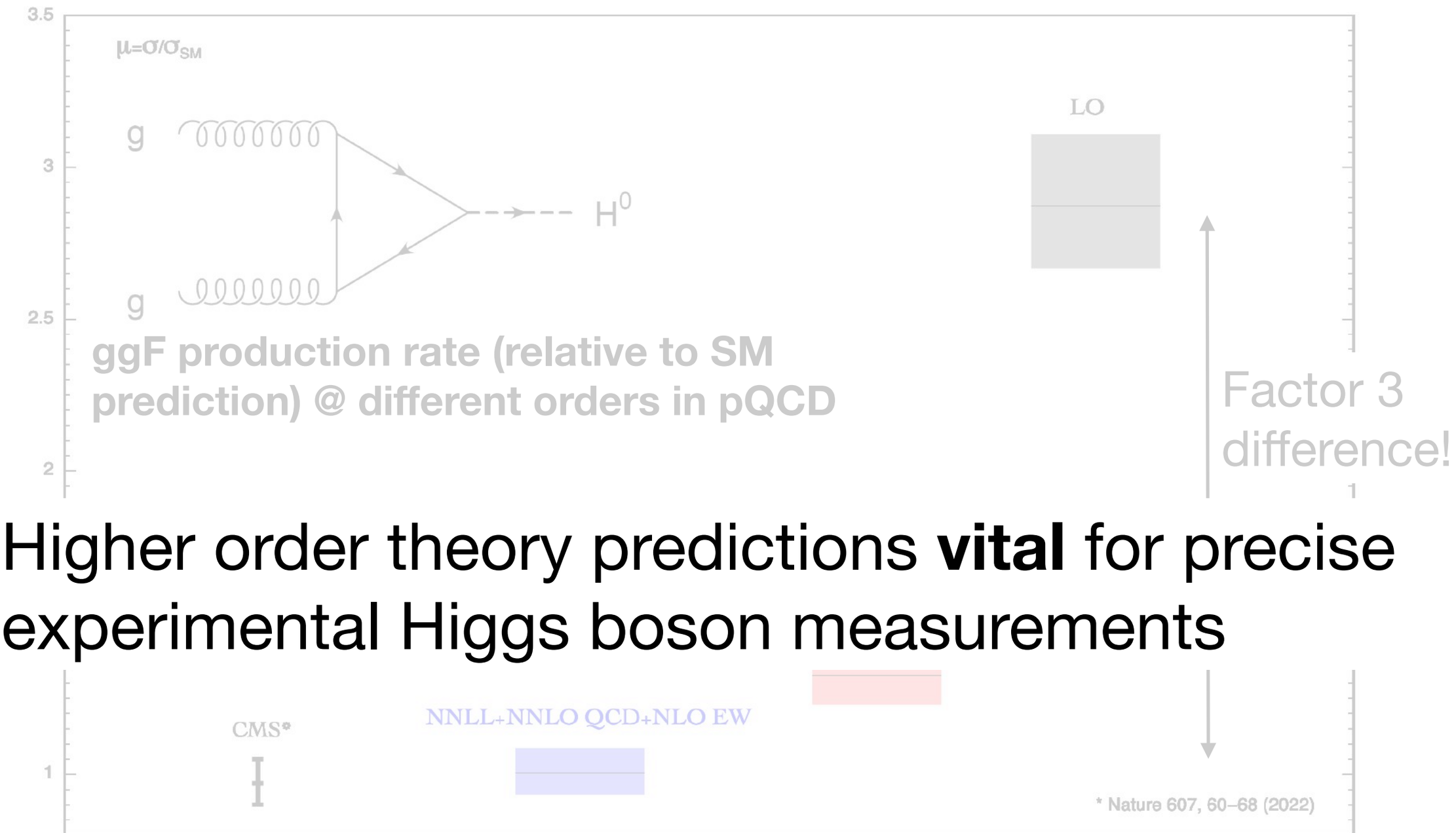
Higgs and QCD?



Factor 3 difference!

From Massimiliano Grazzini @ 10th anniversary of the Higgs boson discovery symposium
https://indico.cern.ch/event/1135177/contributions/4788684/attachments/2474237/4246146/Grazzini_Higgs10.pdf

Higgs and QCD?



Higher order theory predictions **vital** for precise experimental Higgs boson measurements

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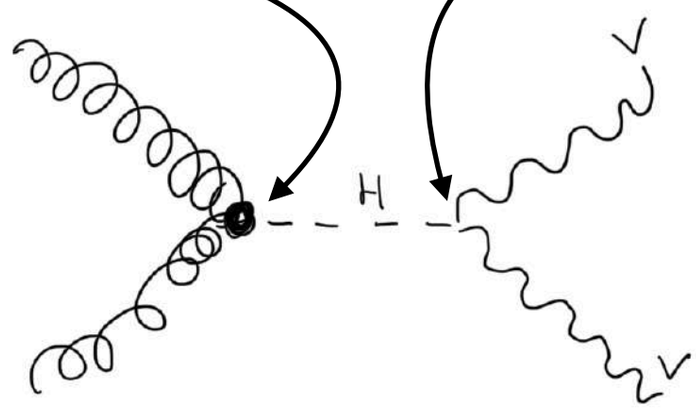
Why theory predictions matter (I)

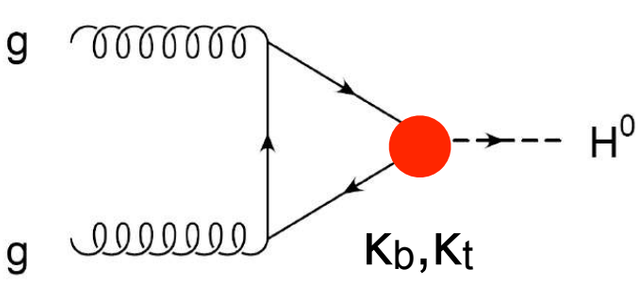
arXiv:1310.8361

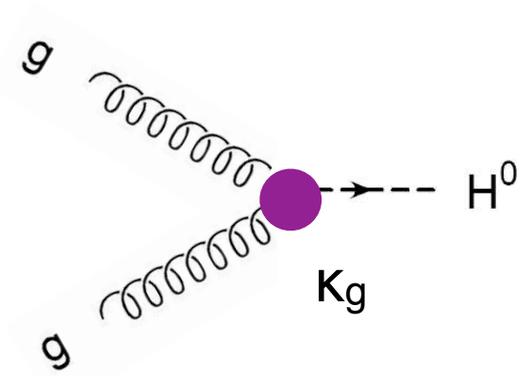
Model	κ_V	κ_b	κ_γ
Singlet Mixing	$\sim 6\%$	$\sim 6\%$	$\sim 6\%$
2HDM	$\sim 1\%$	$\sim 10\%$	$\sim 1\%$
Decoupling MSSM	$\sim -0.0013\%$	$\sim 1.6\%$	$\sim -.4\%$
Composite	$\sim -3\%$	$\sim -(3-9)\%$	$\sim -9\%$
Top Partner	$\sim -2\%$	$\sim -2\%$	$\sim +1\%$

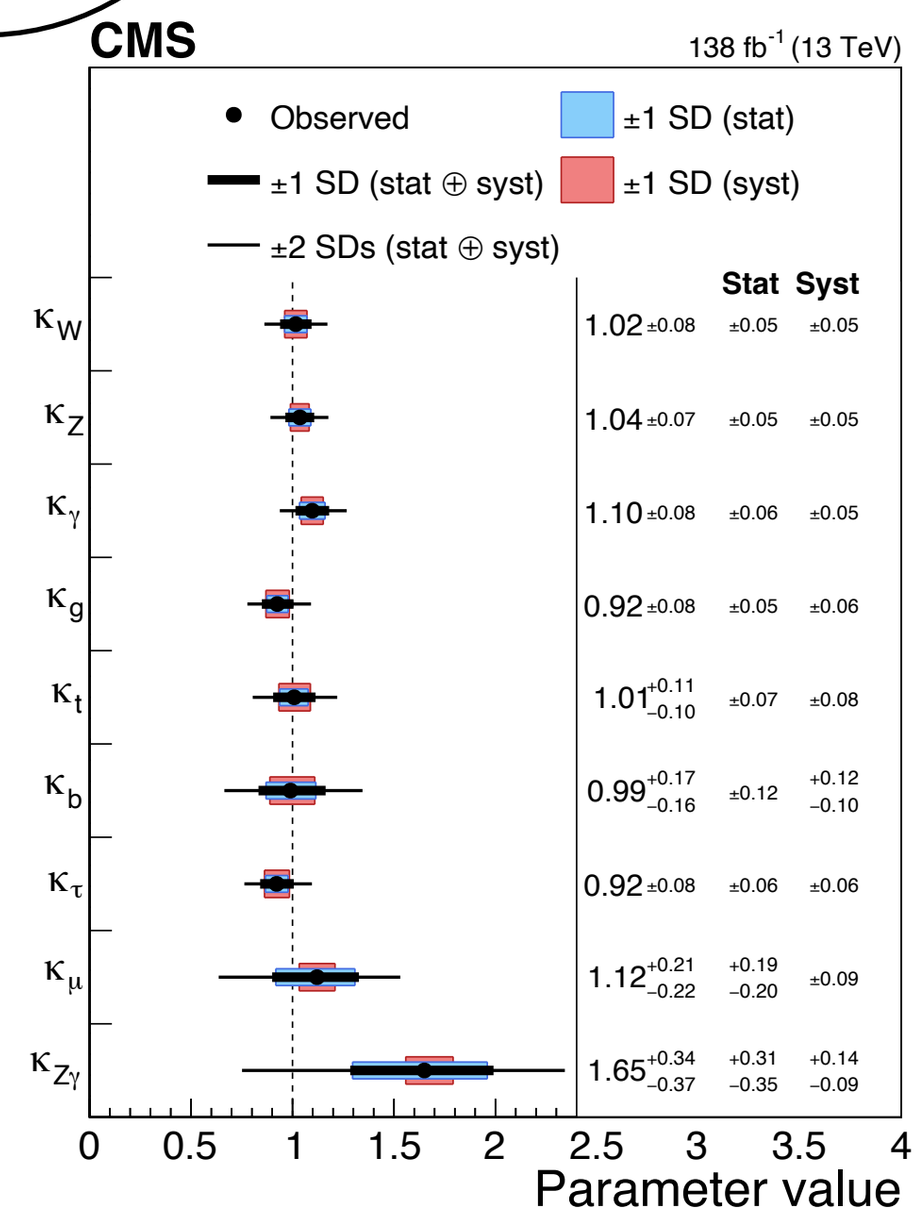
BSM models predicting **%-level deviations in the Higgs couplings** ➔ Precise inclusive measurements important

$$\kappa_j^2 = \frac{\sigma_j}{\sigma_j^{\rm SM}} \qquad \kappa_j^2 = \frac{\Gamma^j}{\Gamma^j_{\rm SM}}$$









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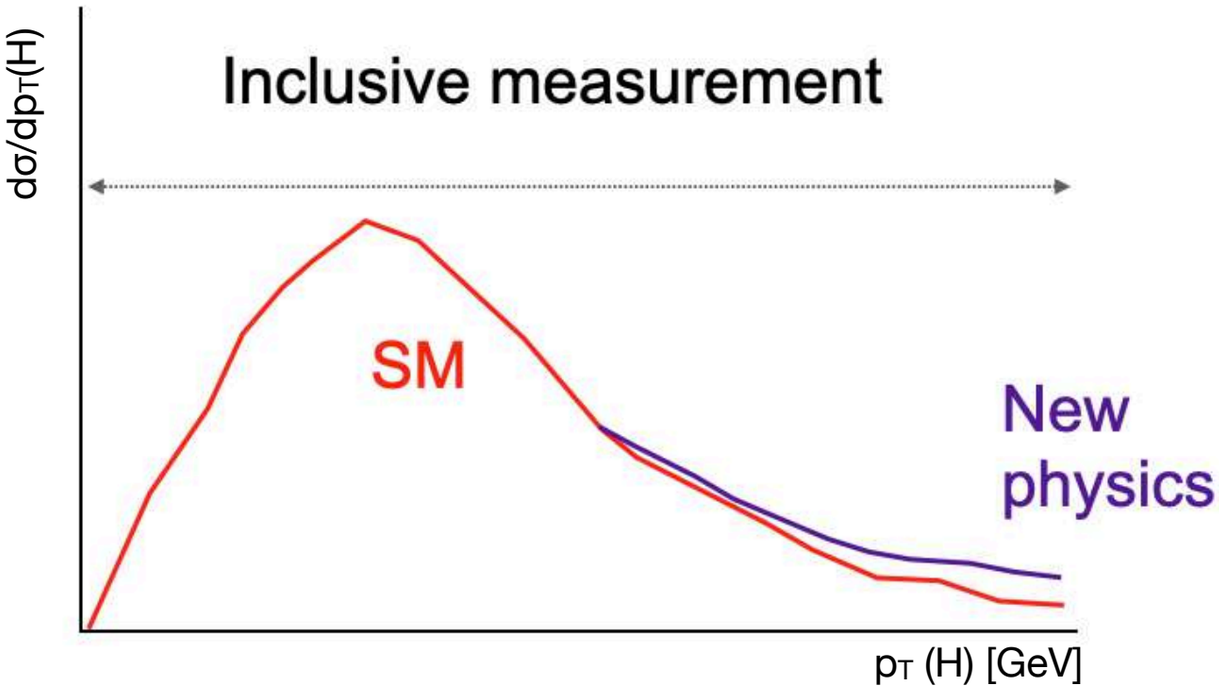
Why theory predictions matter (II)



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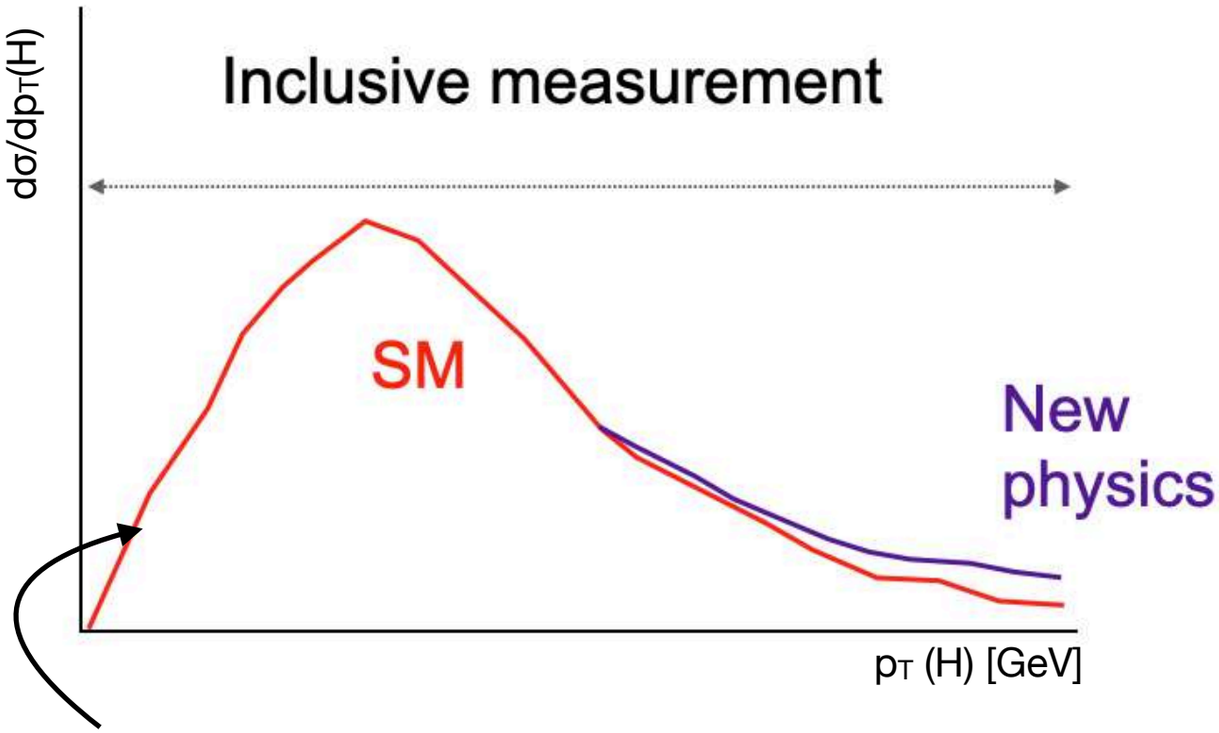

Measured σ compatible with SM

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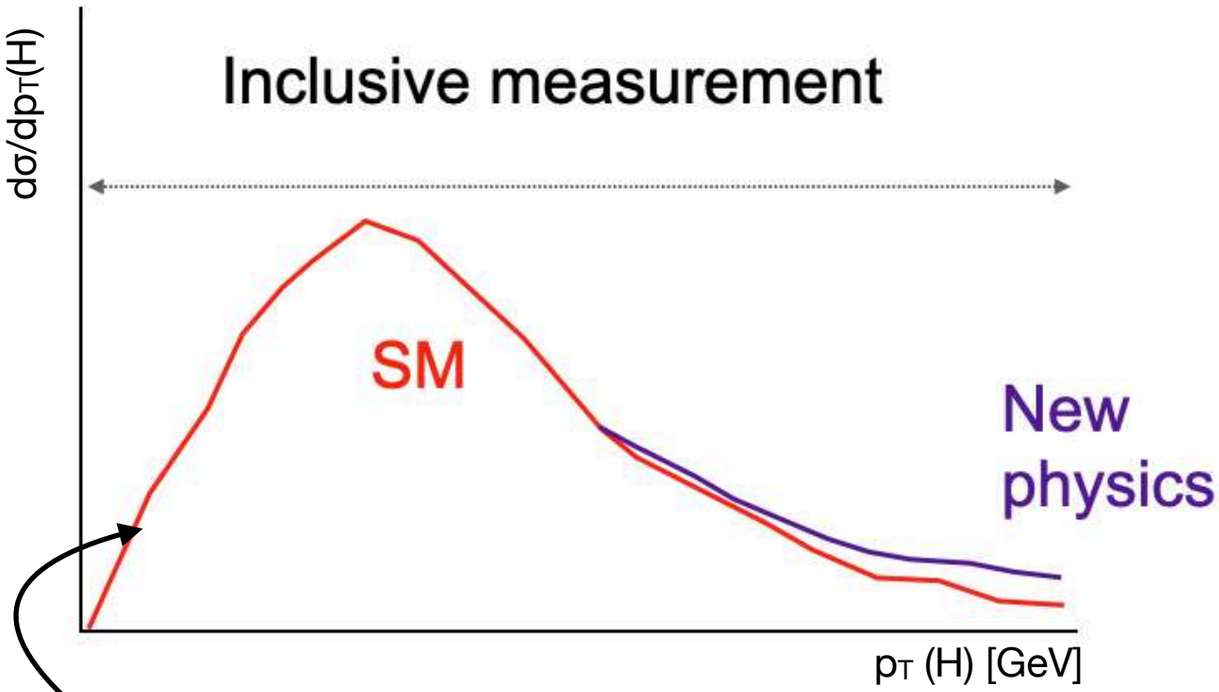

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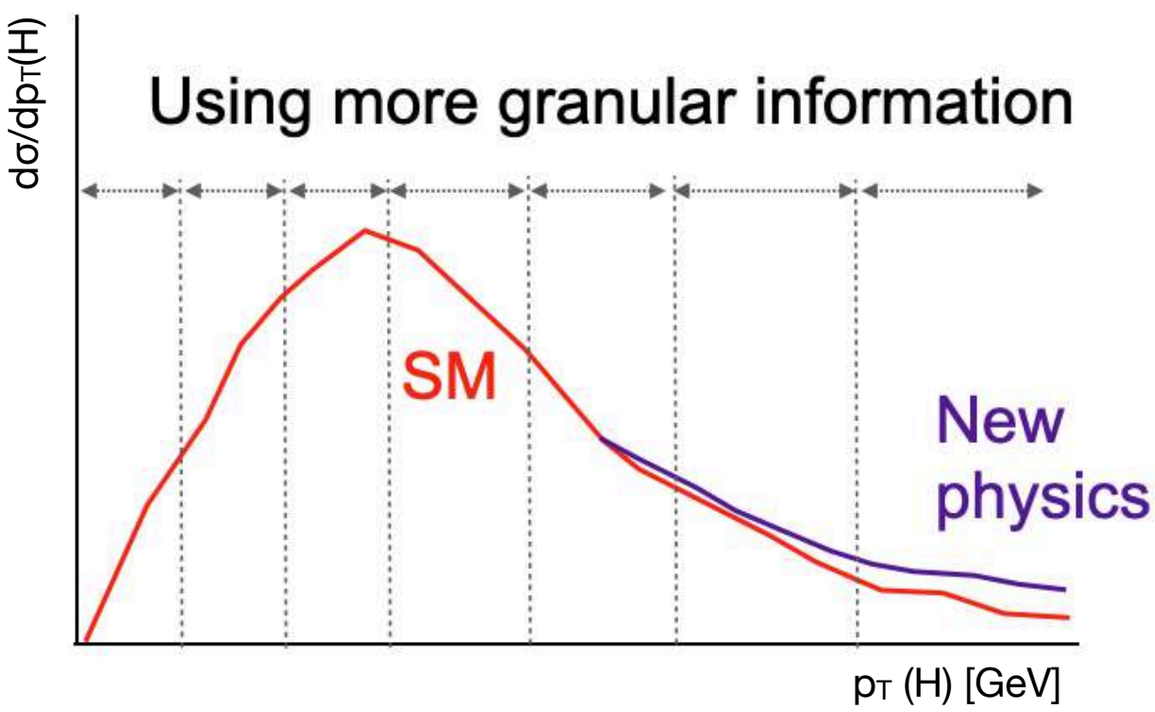

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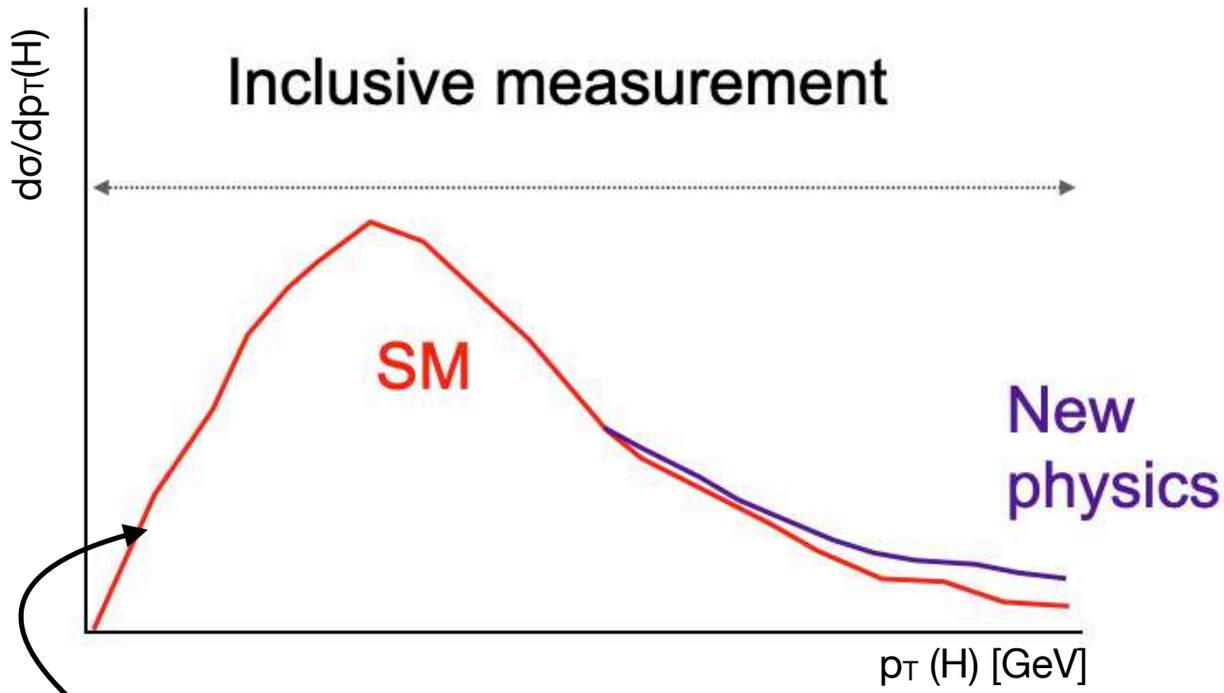

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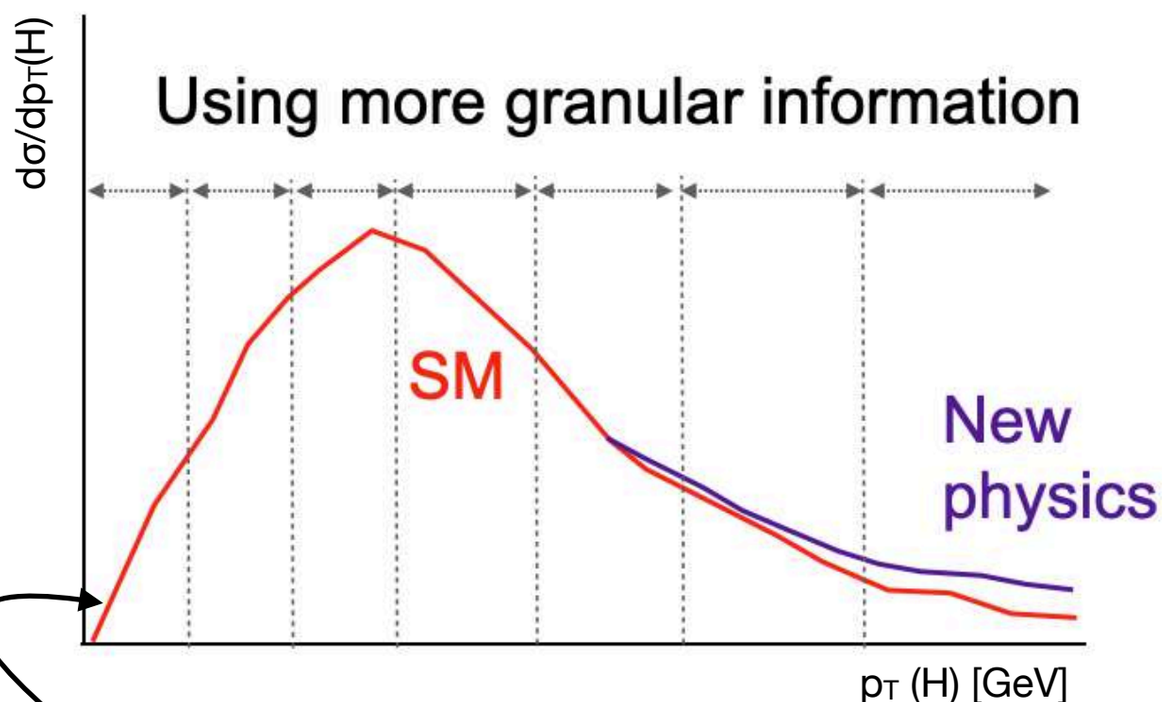

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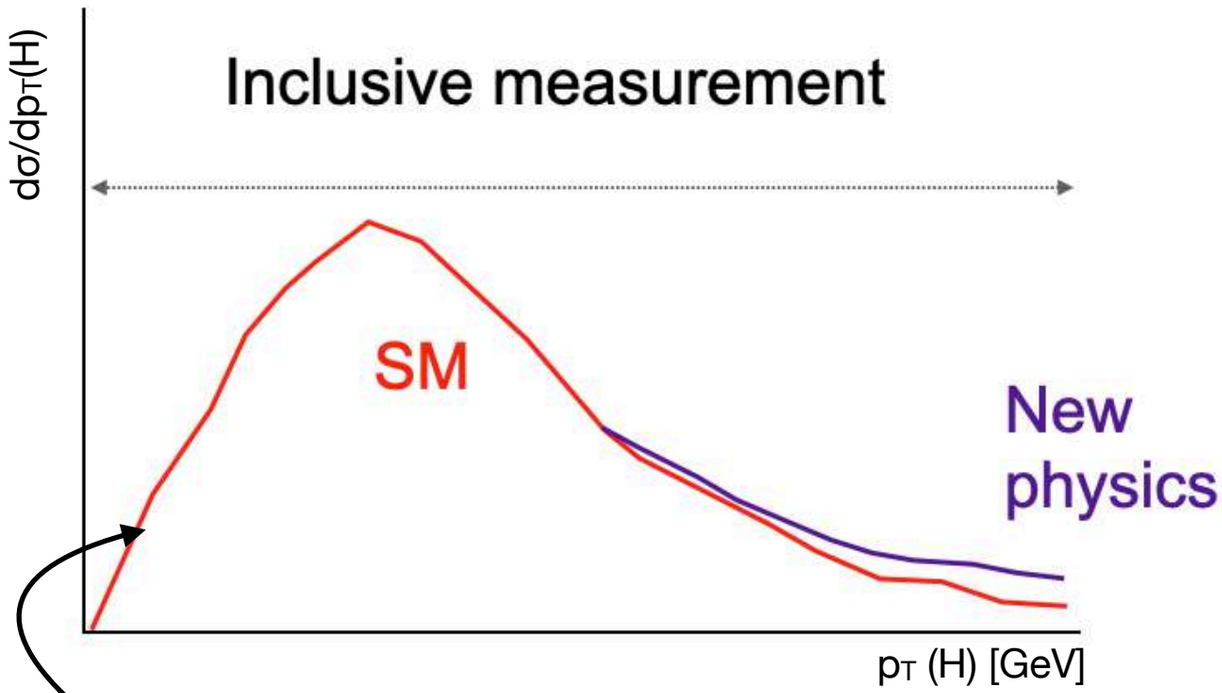

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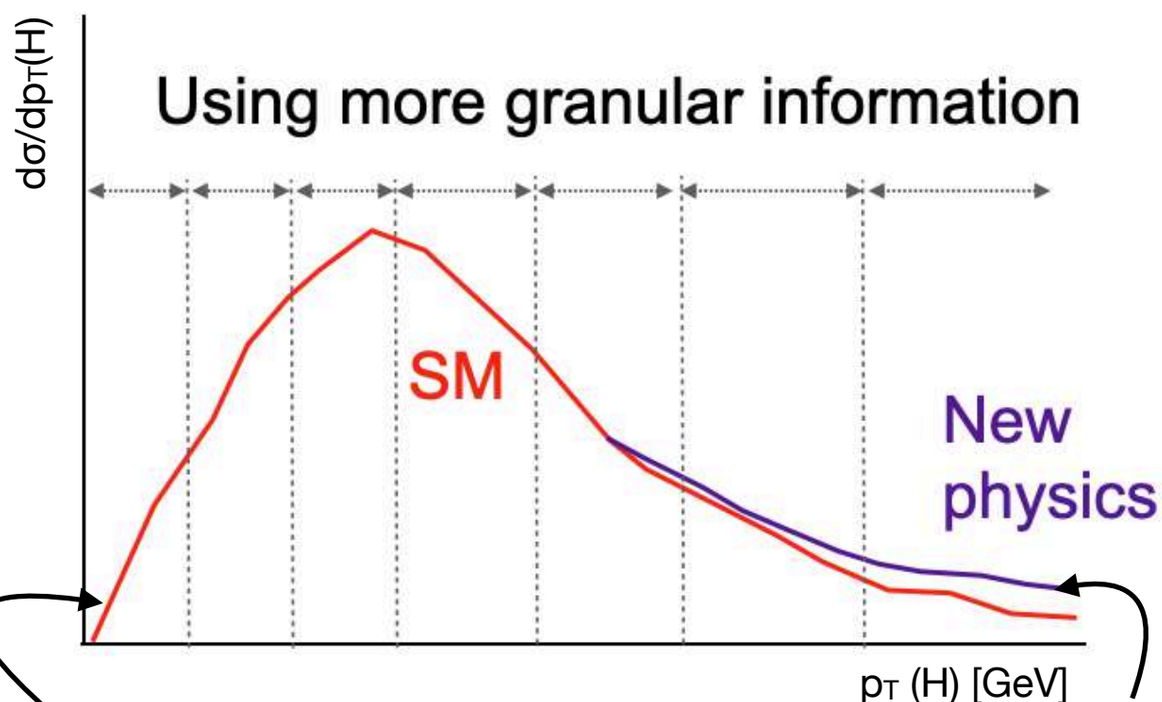

Measured σ compatible with SM

Possible deviation!

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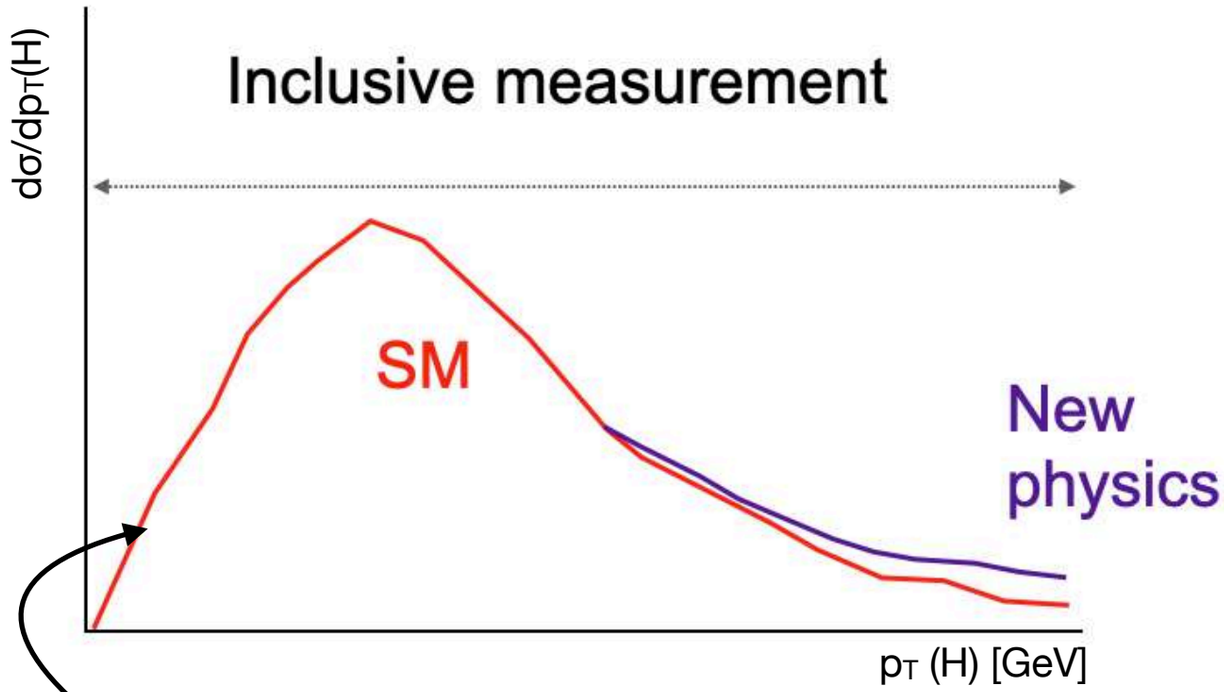

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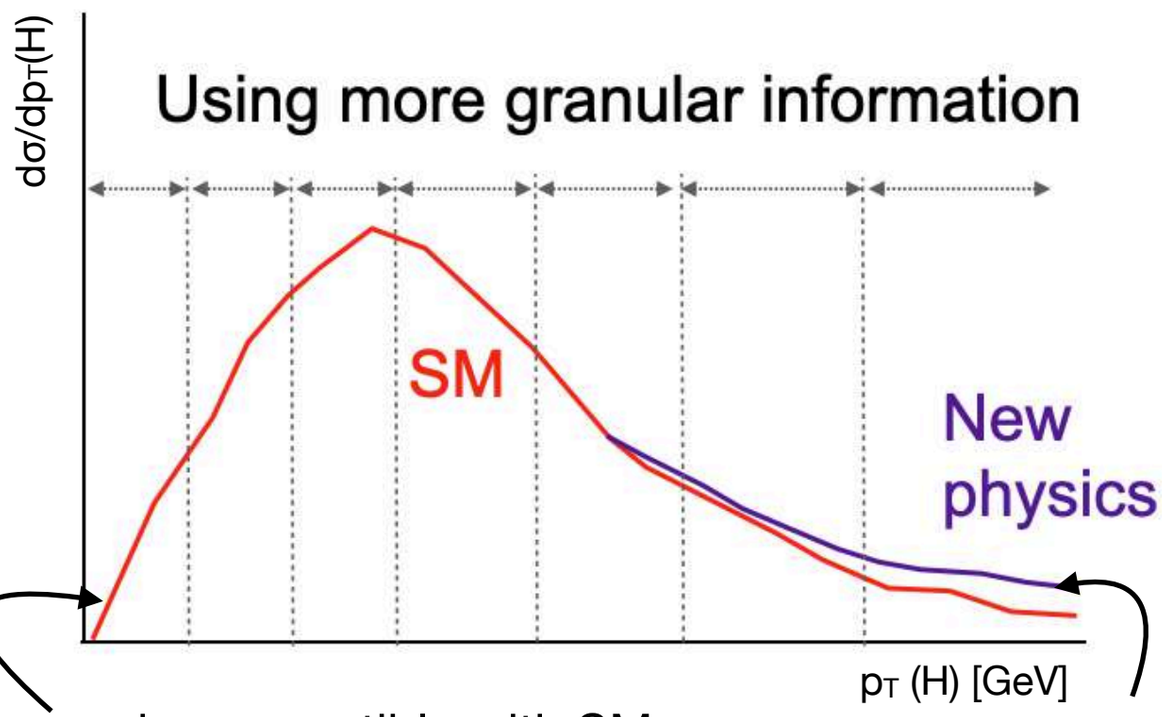


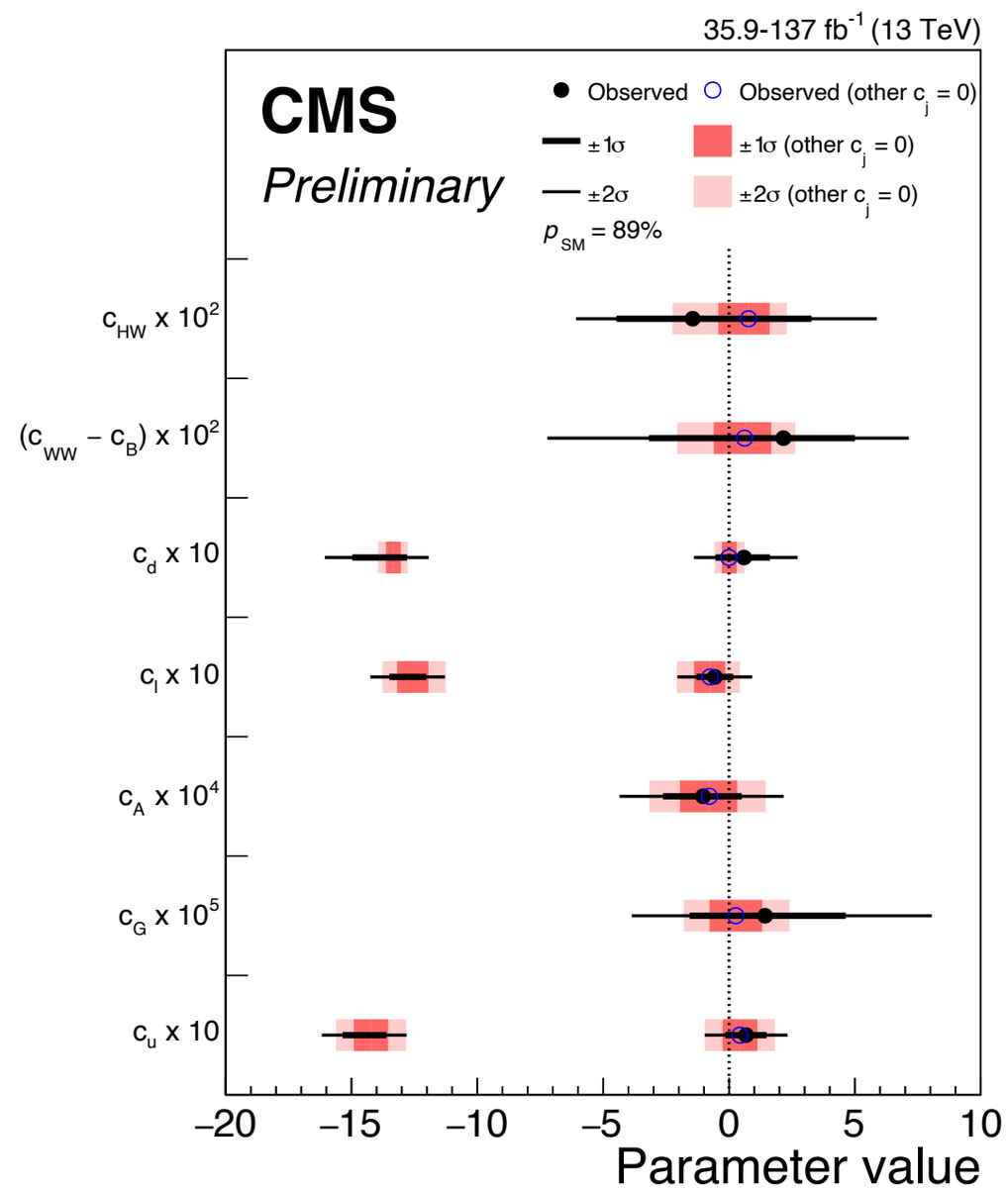
Measured σ compatible with SM

Possible deviation!

Consistent interpretation across processes:

$$\mathscr{L}_{\textbf{EFT}} = \mathscr{L}_{\textbf{SM}} + \Sigma_j \frac{c_j \mathcal{O}_j}{\Lambda^2}$$

e.g. from Higgs boson measurements:



CMS-PAS-HIG-19-005

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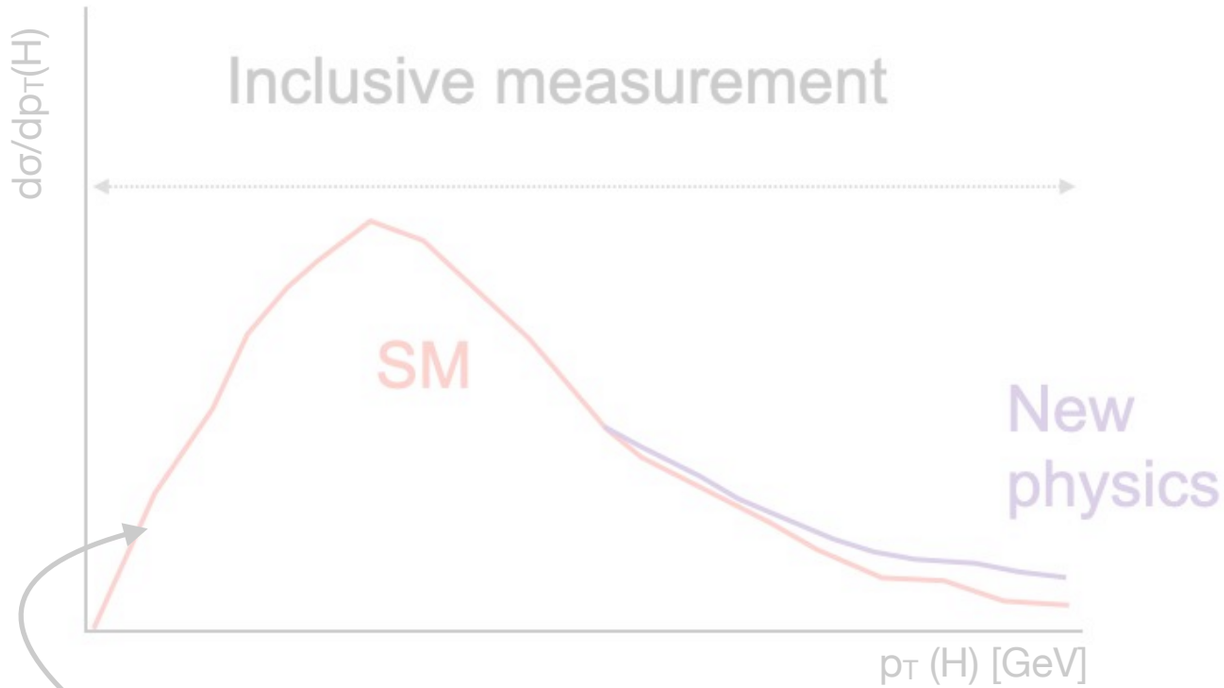

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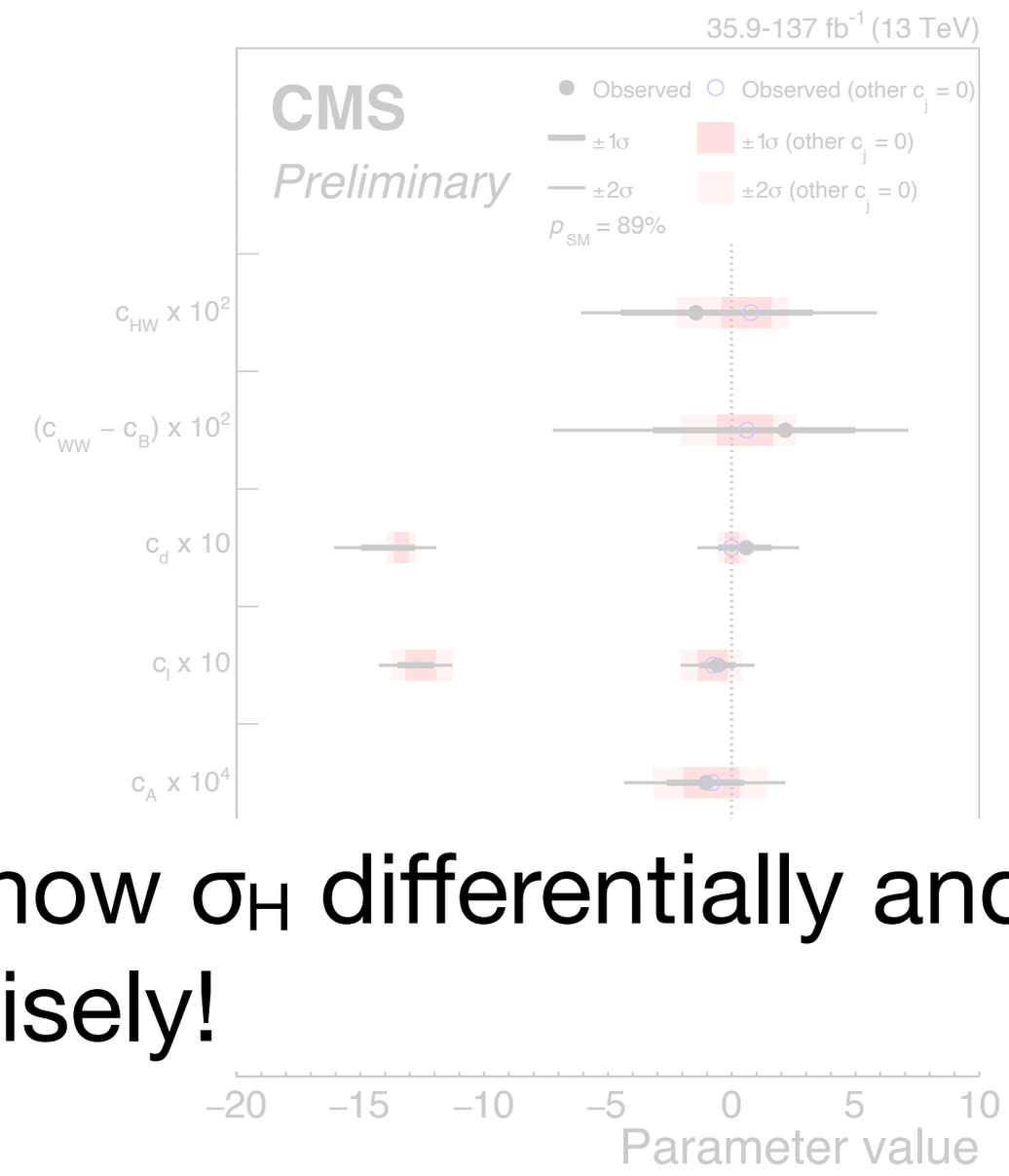
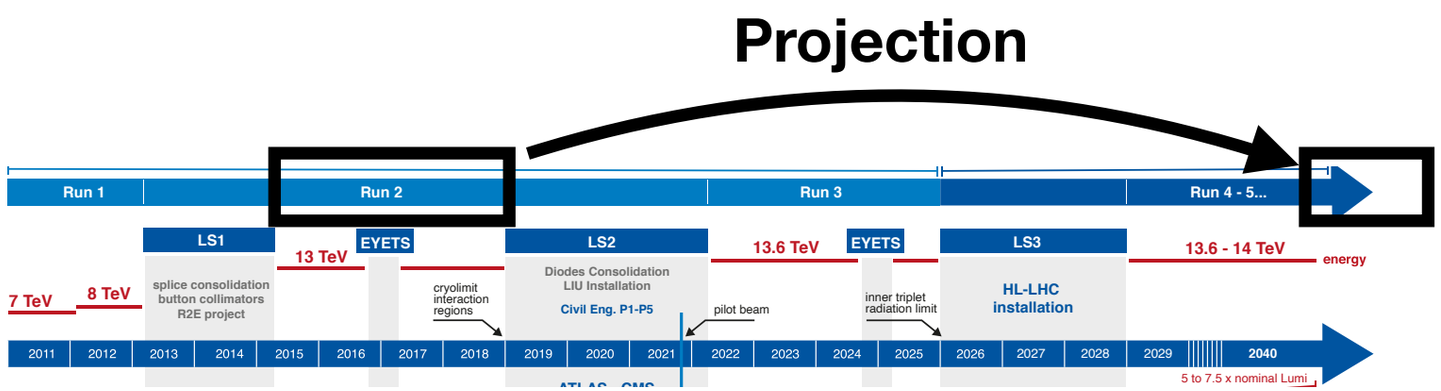


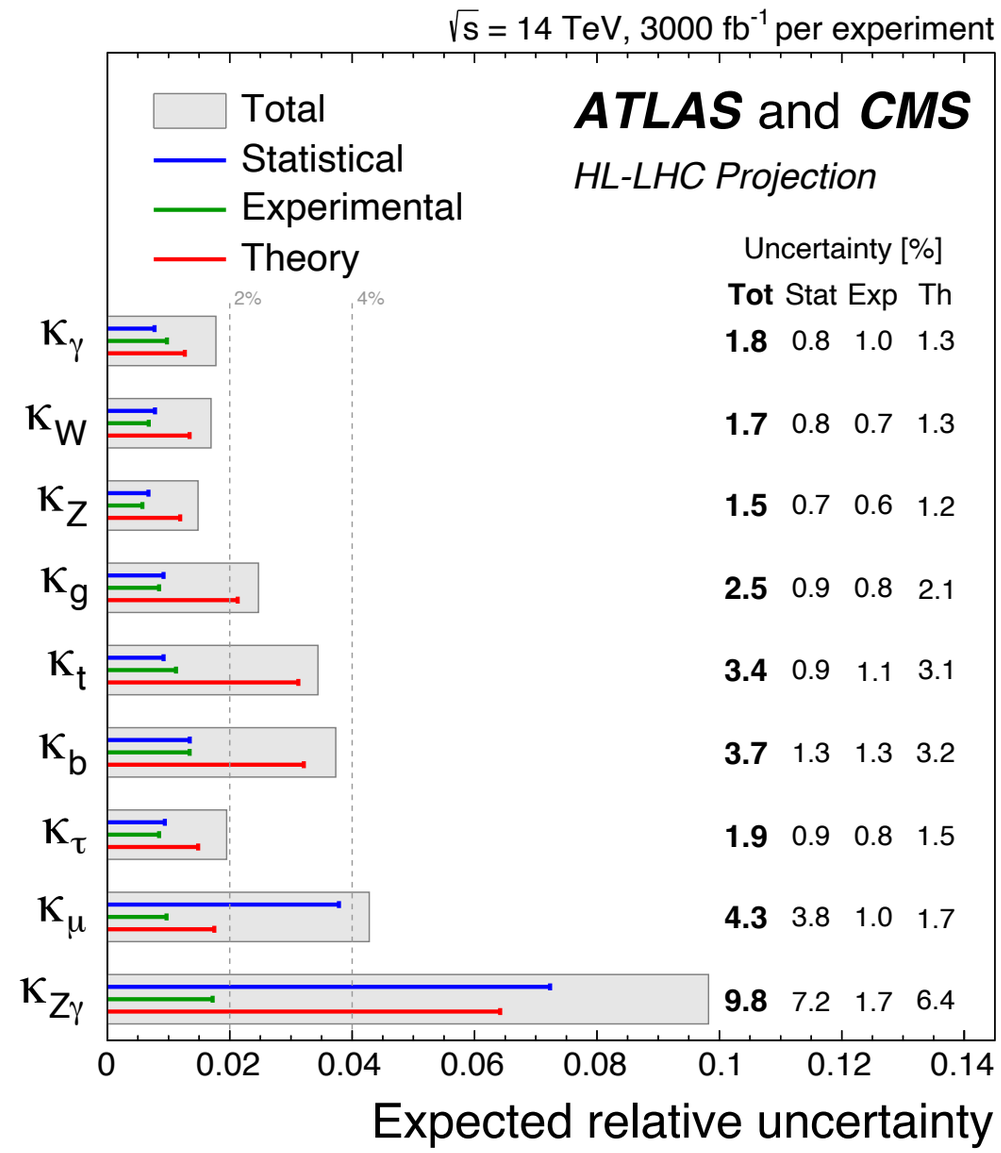
CMS-PAS-HIG-19-005

This only works if we know σ_H differentially and precisely!

Where are we going?



- **Expectations for HL-LHC from existing measurements**
- Assumptions:
  - Efficiencies, resolutions, misidentification rates unchanged from the ~current values
  - Theoretical uncertainties reduced by 1/2
  - Experimental uncertainties scaled down with sqrt(L) until a lower limit is reached



Per-cent level precision on most Higgs couplings, **dominated by theory uncertainties**

Summary

- 10 years after the discovery of the Higgs boson we already have precise experimental measurements of its properties

- Much more to be done ➔ increasing granularity of measurements

- Ultimate precision requires strong interaction with other SM measurements