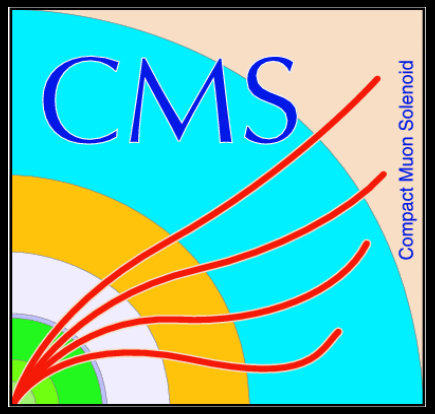
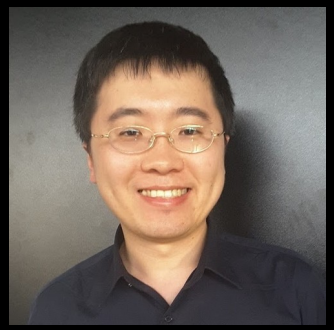


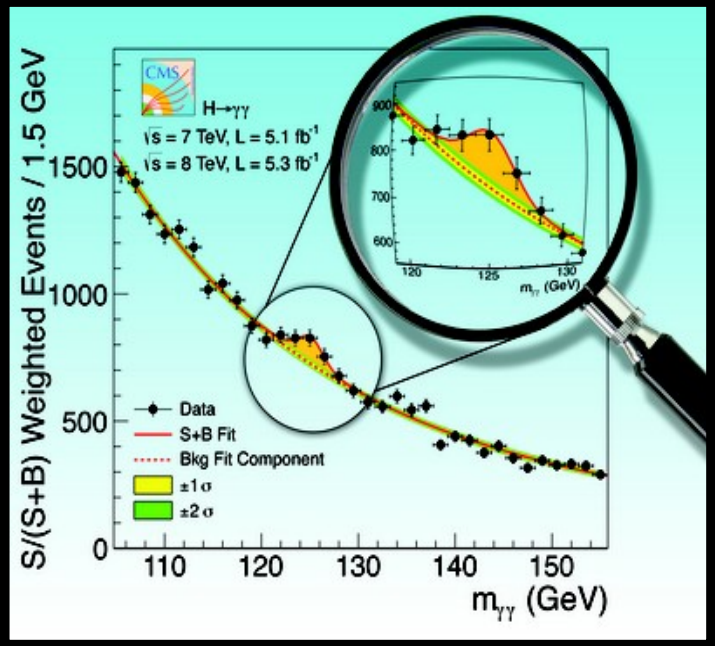
Summary of discussions in
High p_T flavor physics

Abideh (Nadjieh) Jafari
CERN

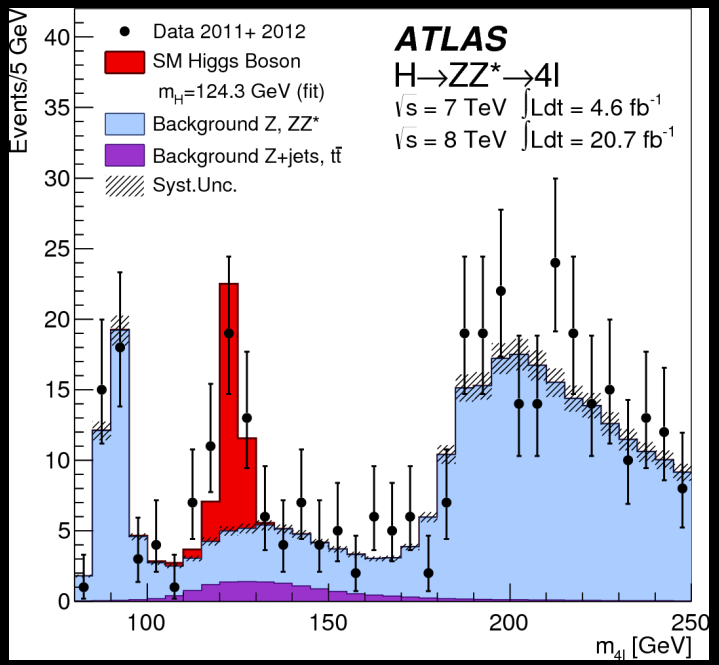
10th International Workshop on the
CKM unitarity triangle

21.09.2018, Heidelberg

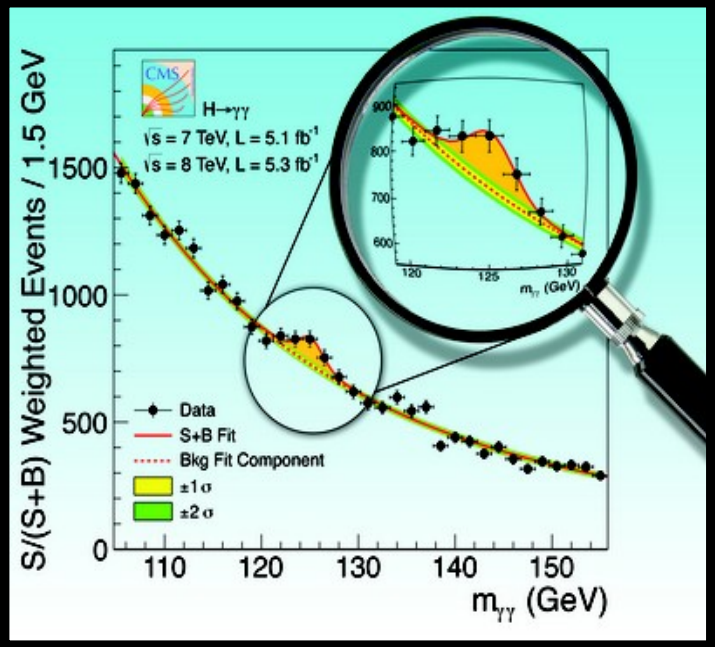




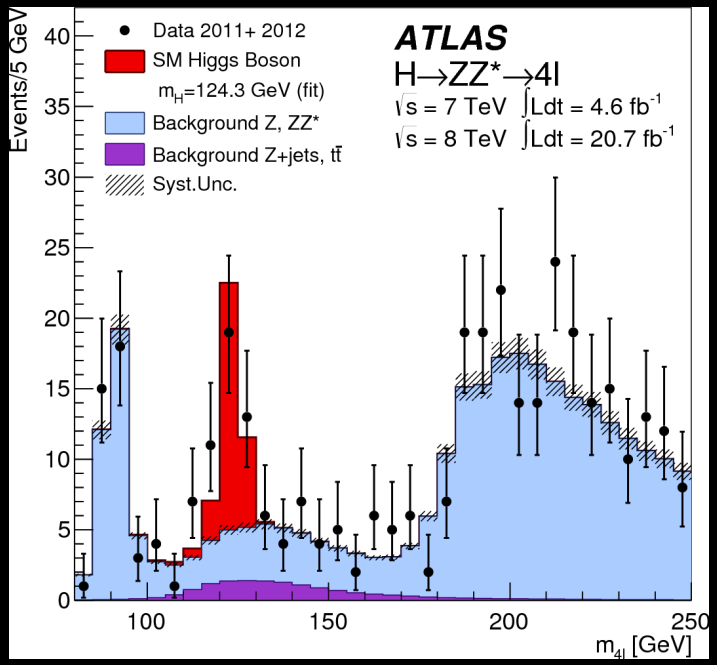
Hot news of 2012!

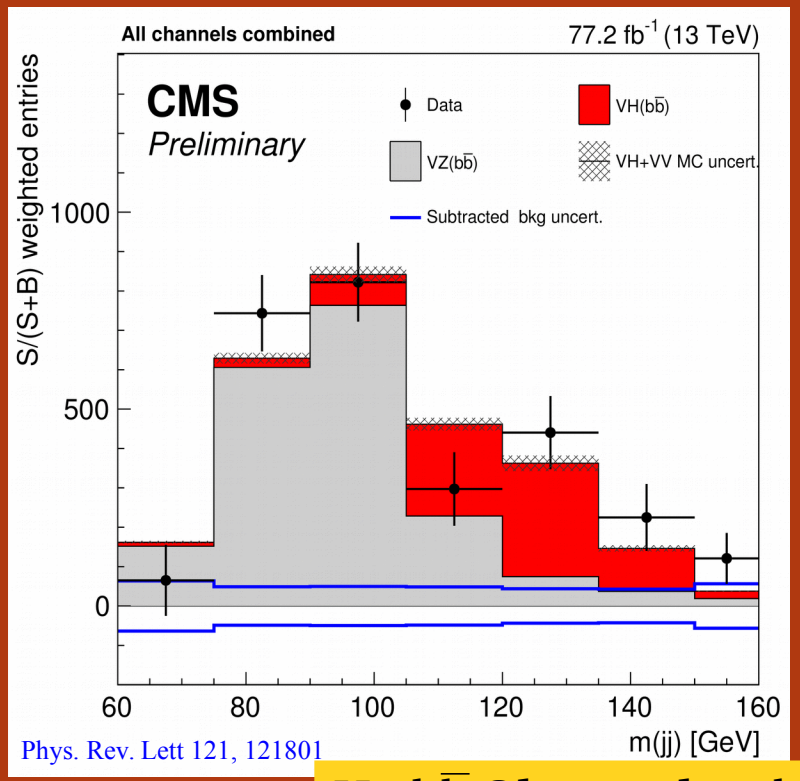


Thank you Higgs for all the fun over the six years!



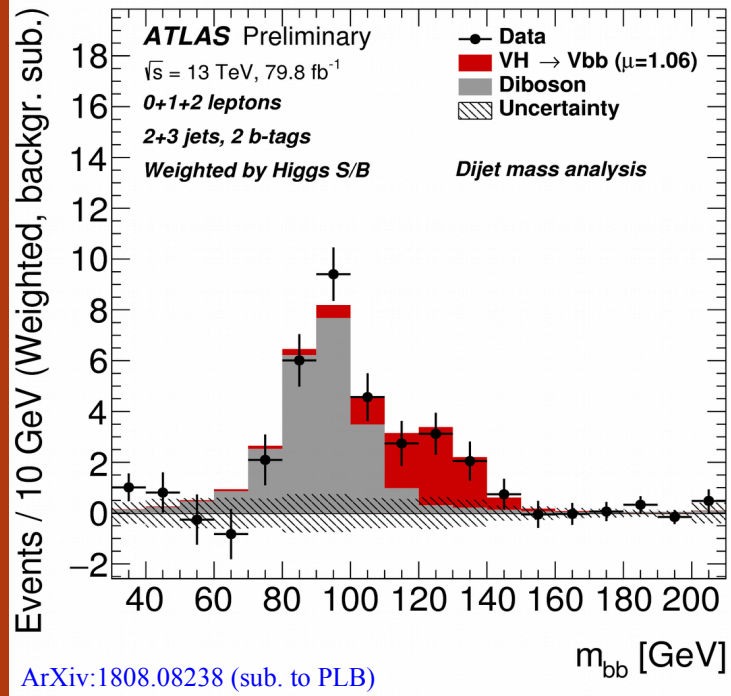
A journey for new discoveries!



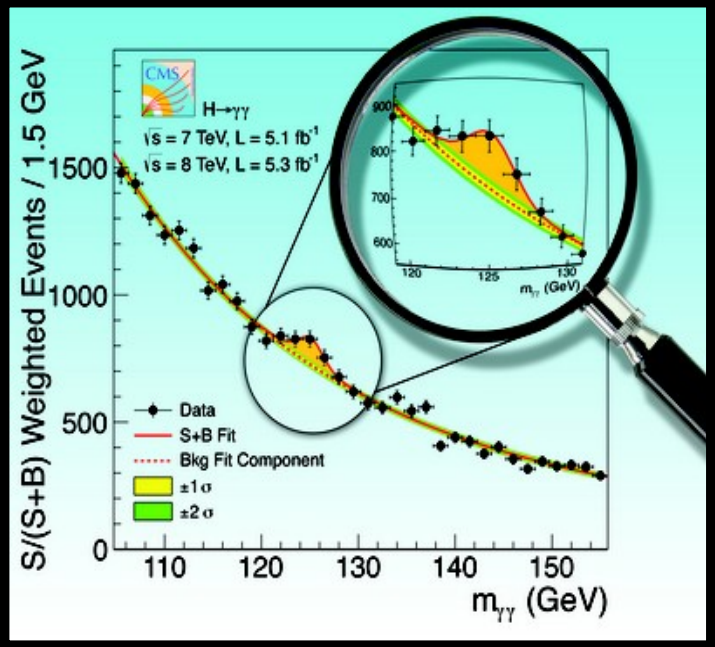


Phys. Rev. Lett 121, 121801

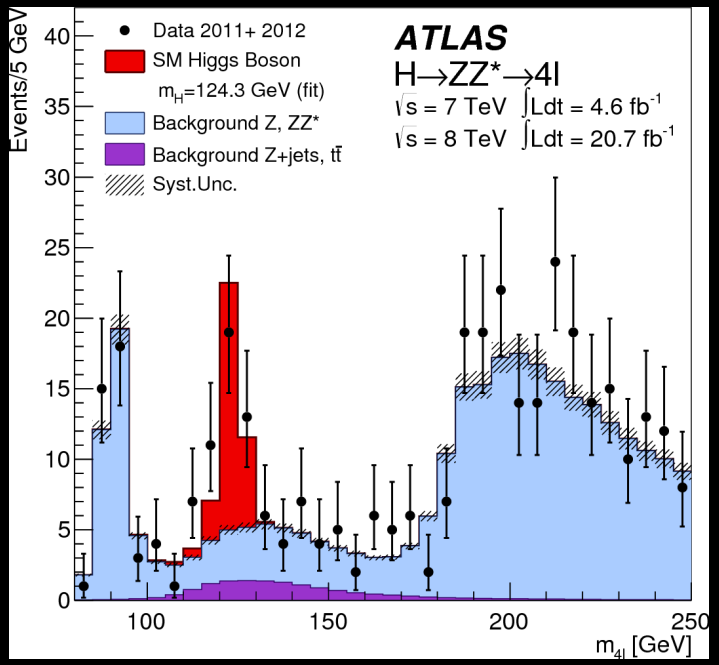
H→bb̄ **Observed** at the LHC!!

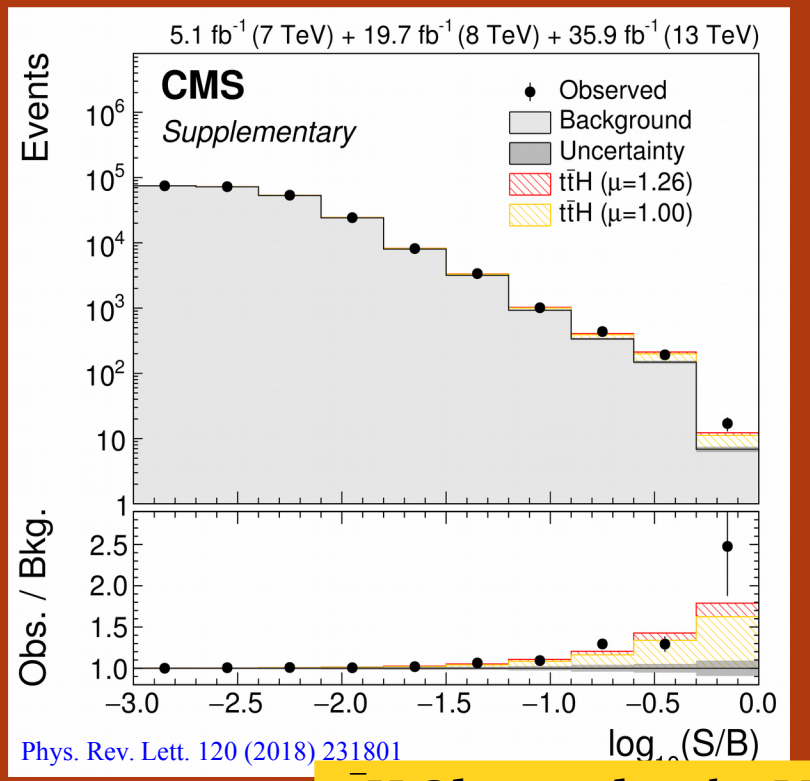


ArXiv:1808.08238 (sub. to PLB)



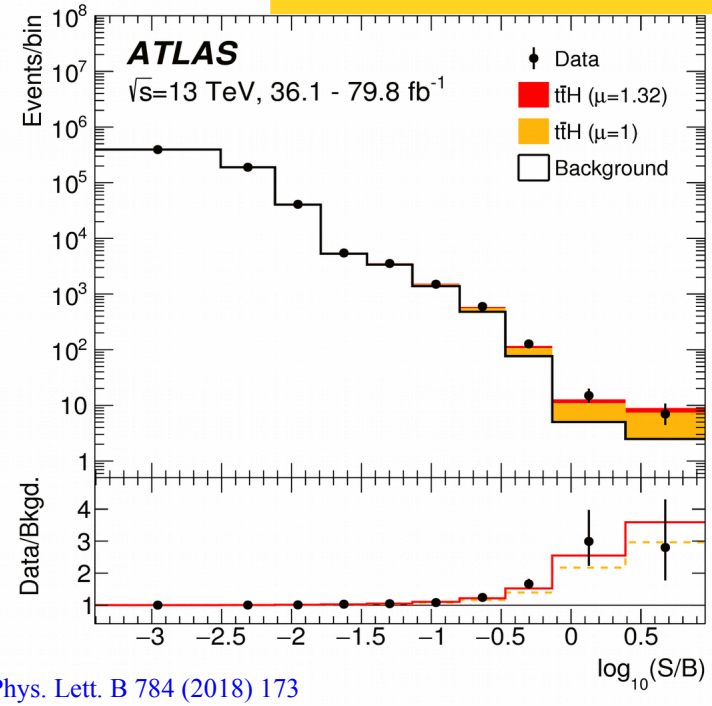
A journey for new discoveries!



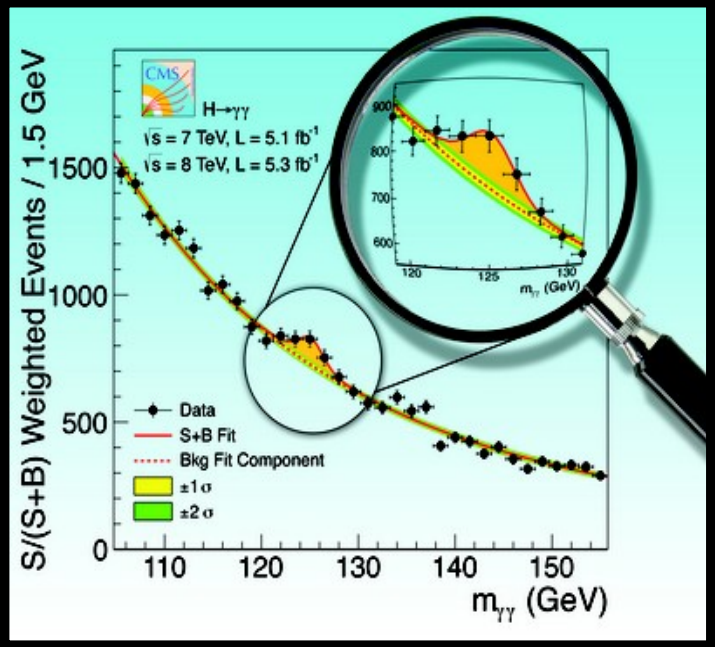


Phys. Rev. Lett. 120 (2018) 231801

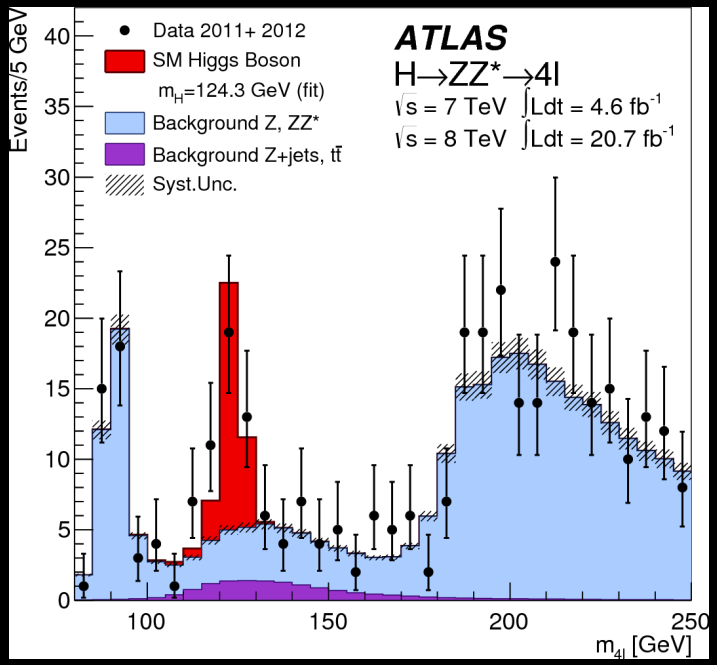
tt̄H Observed at the LHC!!

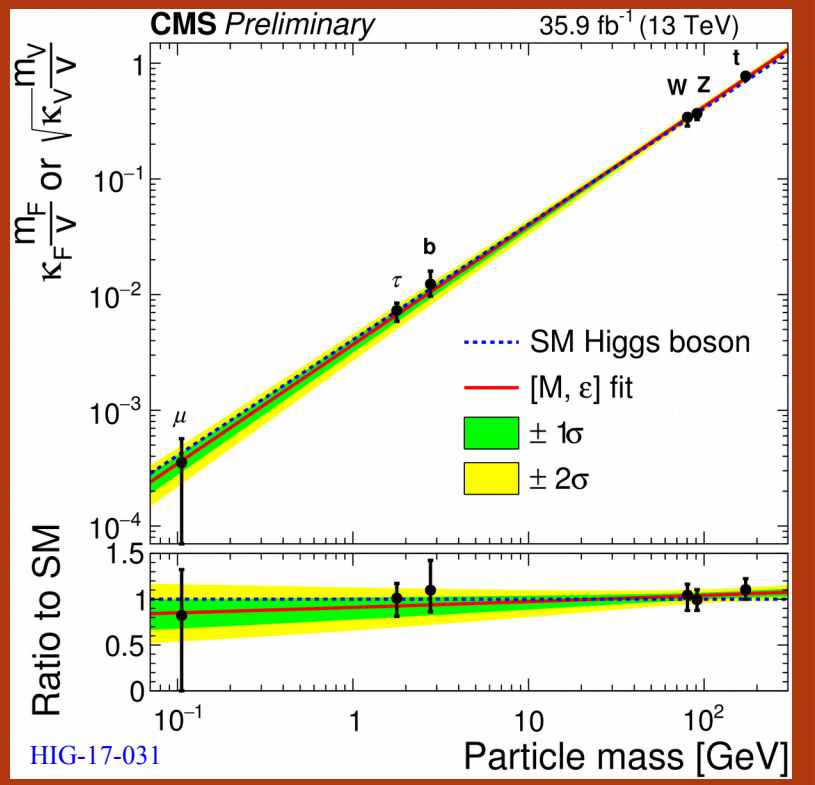


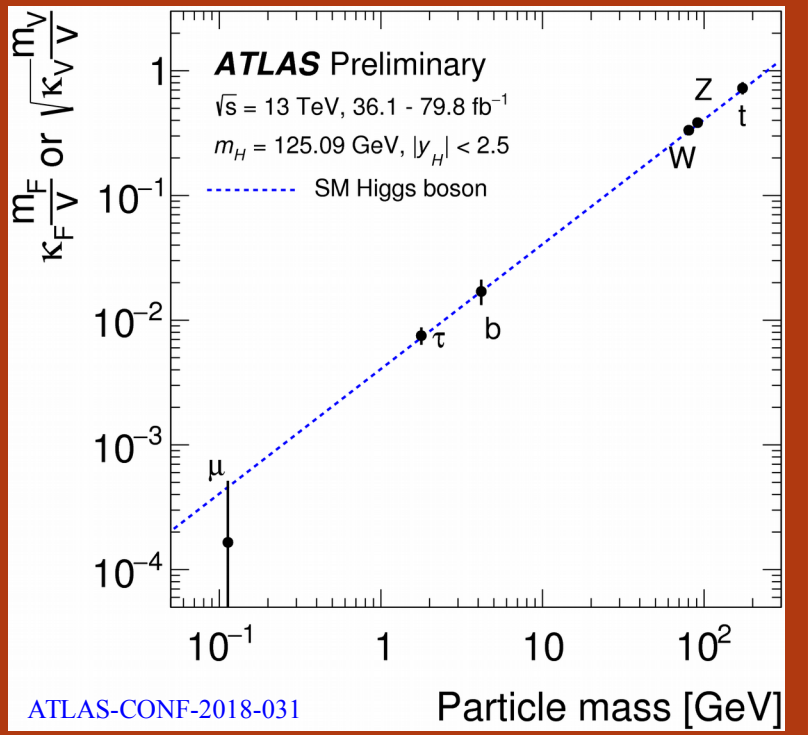
Phys. Lett. B 784 (2018) 173

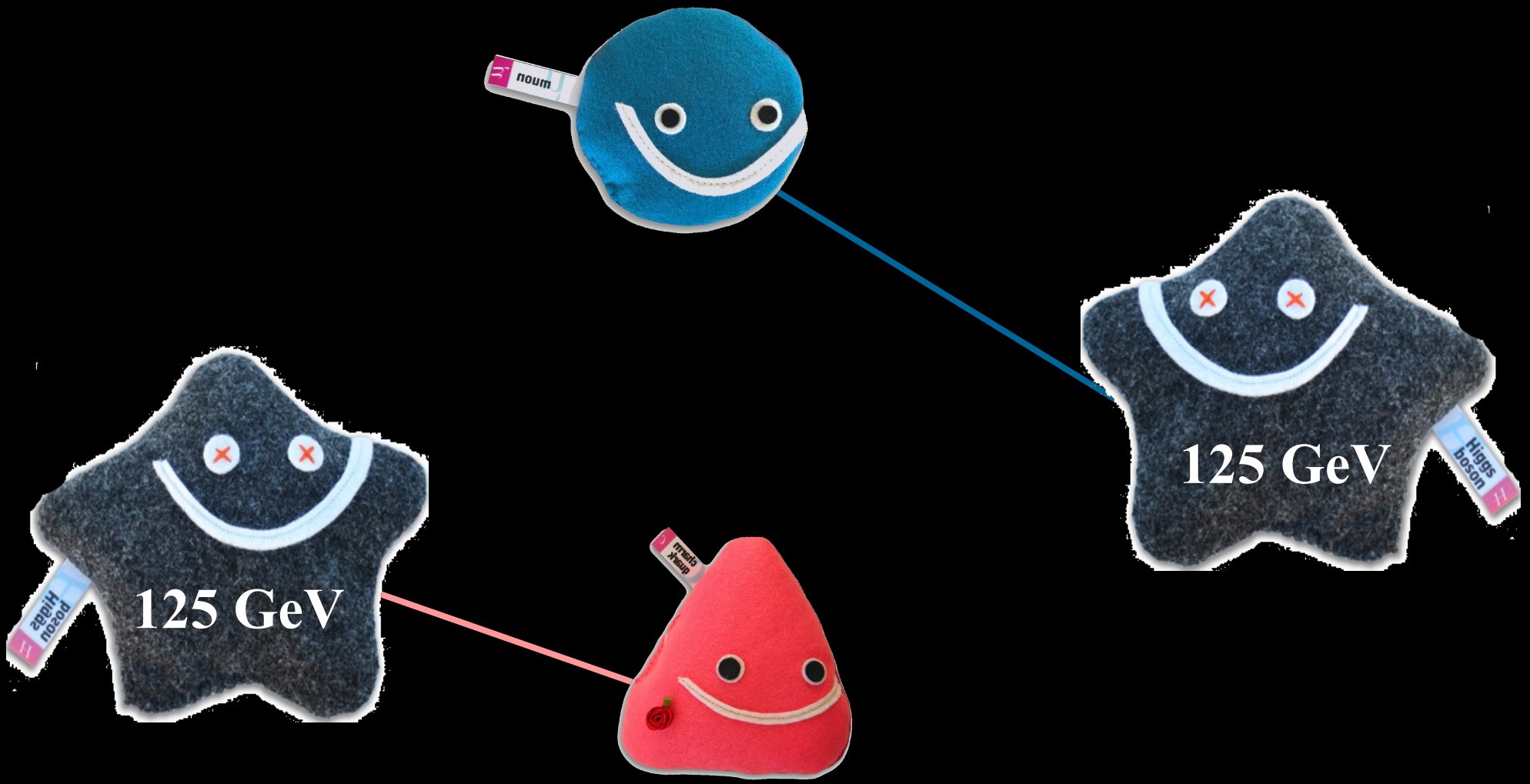


A journey towards precision







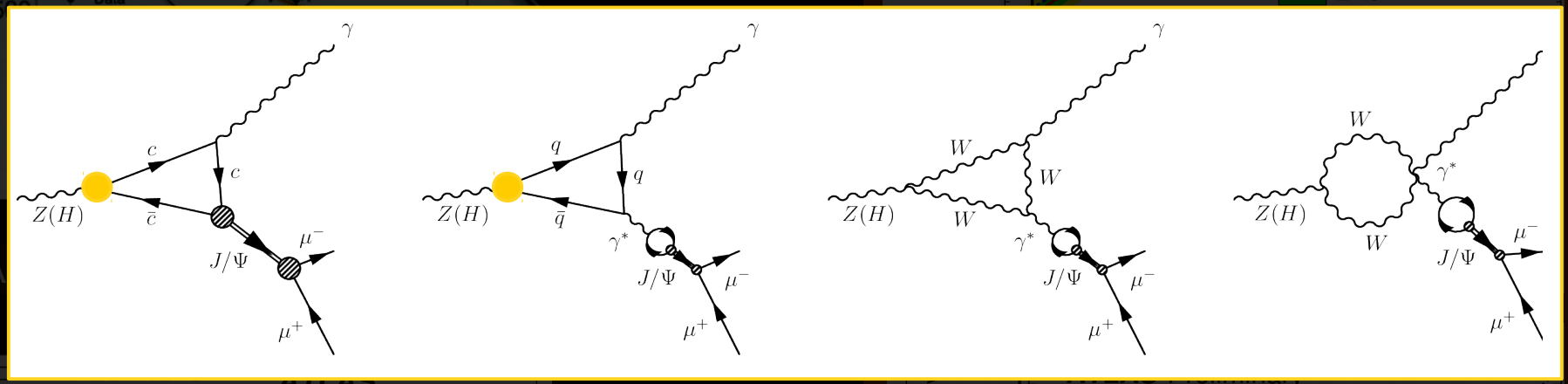


HIGGS RARE DECAYS

Probe H coupling to light & c quarks!

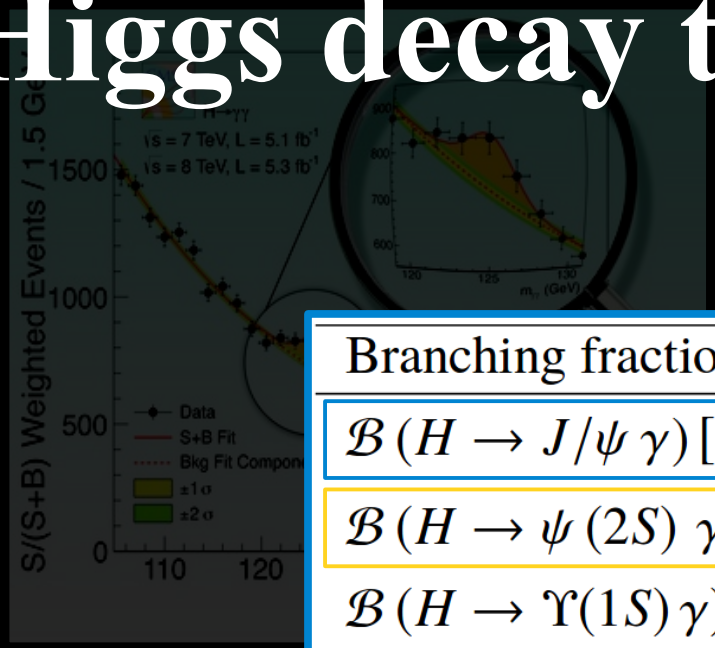
- The LHC *direct limit* on $\sigma_{ZH} \times B(H \to c\bar{c})$ is ~100×SM
- H→ MV complementary to direct H→$c\bar{c}$ searches

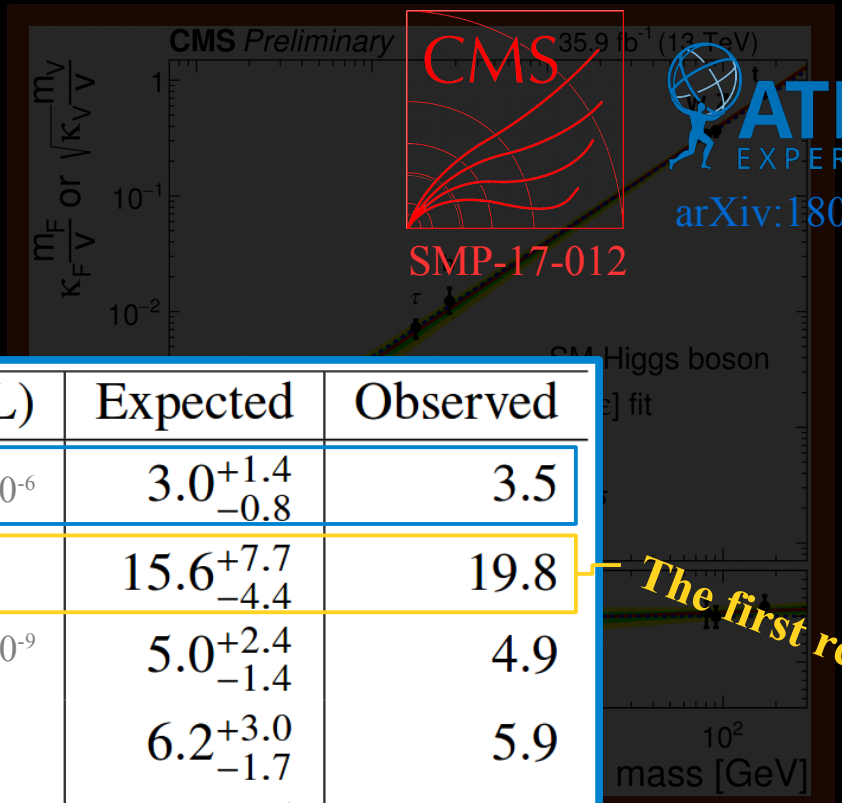
ATLAS EXPERIMENT PRL120 (2018) 211802



H→ $M\gamma$ at LHC 13 TeV		
H→φγ →$K^+K^-\gamma$	ATLAS EXPERIMENT JHEP 07(2018) 127	
H→ργ →$\pi^+\pi^-\gamma$	ATLAS EXPERIMENT JHEP 07(2018) 127	
H→ψ/ϒγ →$\mu^+\mu^-\gamma$	ATLAS EXPERIMENT arXiv:1807.00802	CMS CMS-SMP-17-012

Higgs decay to $M\gamma$



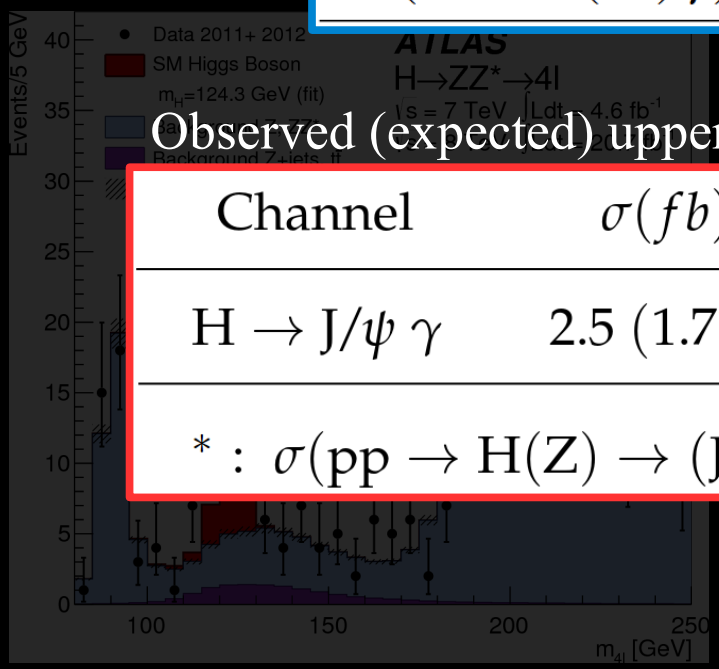


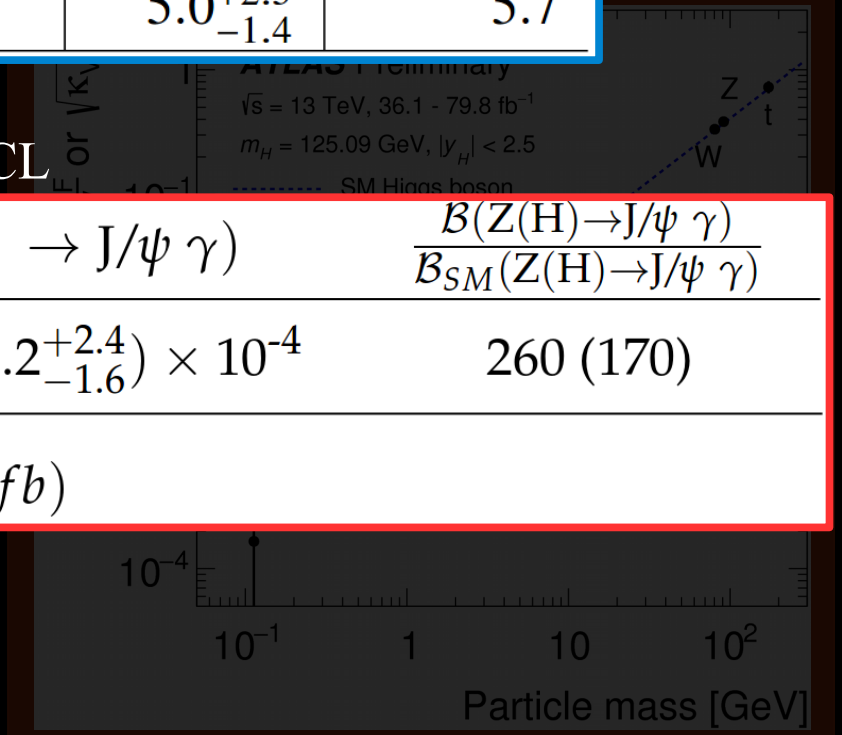
CMS SMP-17-012

ATLAS EXPERIMENT arXiv:1807.00802

Branching fraction limit (95% CL)		Expected	Observed
$\mathcal{B}(H \to J/\psi\,\gamma)\,[\,10^{-4}\,]$	SM: 10^{-6}	$3.0^{+1.4}_{-0.8}$	3.5
$\mathcal{B}(H \to \psi(2S)\,\gamma)\,[\,10^{-4}\,]$		$15.6^{+7.7}_{-4.4}$	19.8
$\mathcal{B}(H \to \Upsilon(1S)\,\gamma)\,[\,10^{-4}\,]$	SM: 10^{-9}	$5.0^{+2.4}_{-1.4}$	4.9
$\mathcal{B}(H \to \Upsilon(2S)\,\gamma)\,[\,10^{-4}\,]$		$6.2^{+3.0}_{-1.7}$	5.9
$\mathcal{B}(H \to \Upsilon(3S)\,\gamma)\,[\,10^{-4}\,]$		$5.0^{+2.5}_{-1.4}$	5.7

The first result!





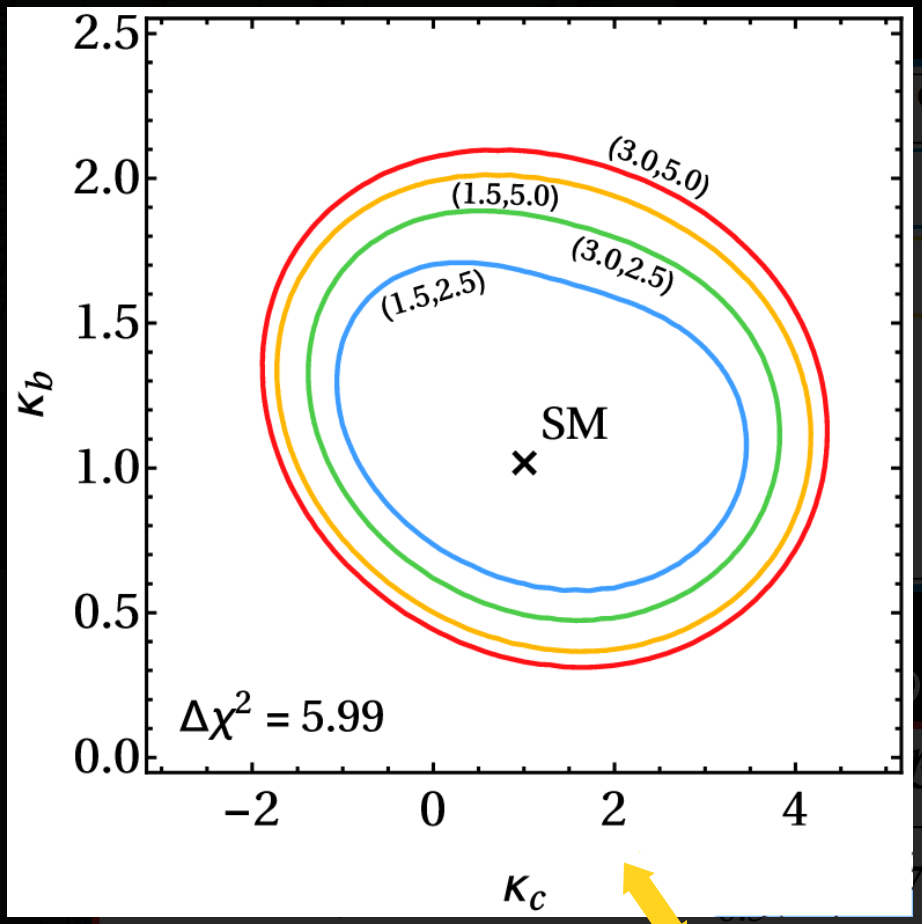
Observed (expected) upper limits at 95% CL

Channel	$\sigma(fb)$ *	$\mathcal{B}(\mathrm{H} \to \mathrm{J}/\psi\,\gamma)$	$\frac{\mathcal{B}(\mathrm{Z(H)}\to\mathrm{J}/\psi\,\gamma)}{\mathcal{B}_{SM}(\mathrm{Z(H)}\to\mathrm{J}/\psi\,\gamma)}$
$\mathrm{H} \to \mathrm{J}/\psi\,\gamma$	$2.5\ (1.7^{+0.8}_{-0.5})$	$7.6\ (5.2^{+2.4}_{-1.6}) \times 10^{-4}$	260 (170)

* : $\sigma(\mathrm{pp} \to \mathrm{H(Z)} \to (\mathrm{J}/\psi \to \mu\mu)\gamma)\ (fb)$

Higgs p_T and κ_c

Bishara, Haisch, Monni, Re: 1606.09253 (PRL)



95% C.I. after profiling over κ_b

LHC Run I: $[-16, 18]$

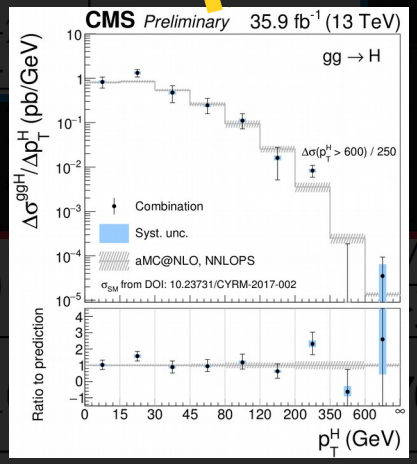
LHC Run II: $[-1.4, 3.8]$

HL-LHC: $[-0.6, 3.0]$

CMS with 35.9 fb^{-1} (13 TeV)

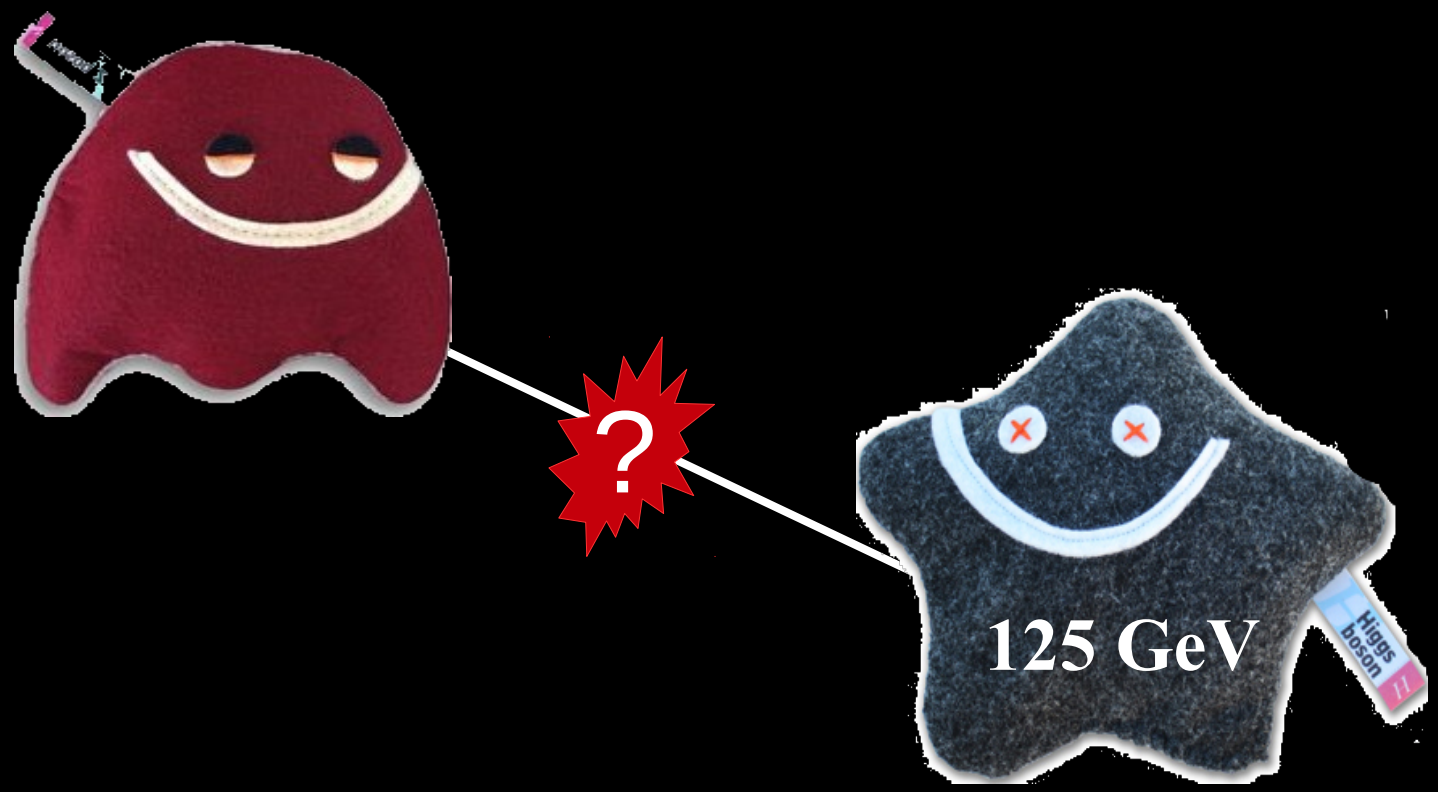
$-8.7 < \kappa_c < 10.6$

PAS HIG-17-028



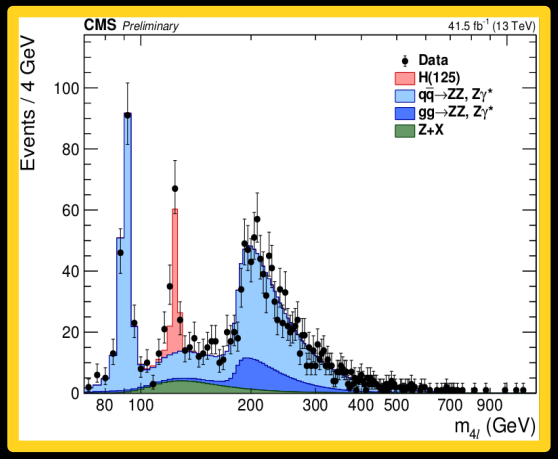
	experimental [%]	theoretical [%]	$\kappa_c \in$
S_1	1.5	2.5	[-0.6, 3.0]
S_2	3.0	2.5	[-0.9, 3.3]
S_3	1.5	5.0	[-1.2, 3.6]
S_4	3.0	5.0	[-1.3, 3.7]

Definitely to be followed at HL-LHC (and beyond?)



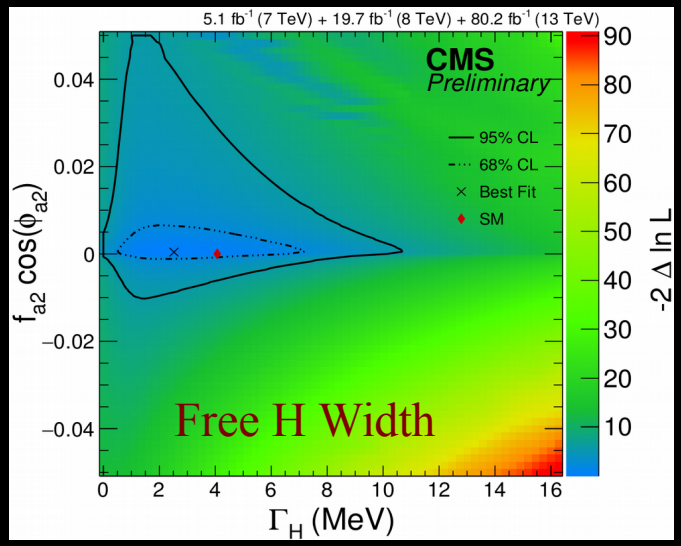
HIGGS ANOMALOUS COUPLINGS

Higgs HVV anomalous couplings

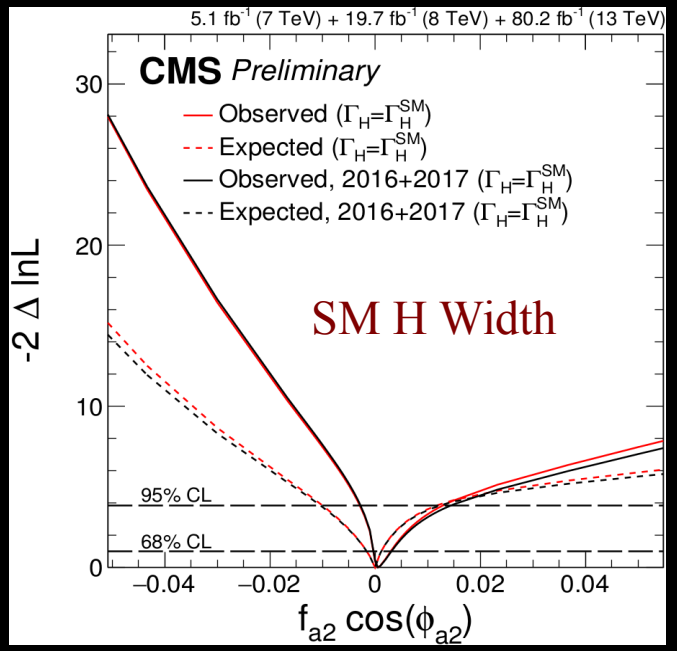


CMS

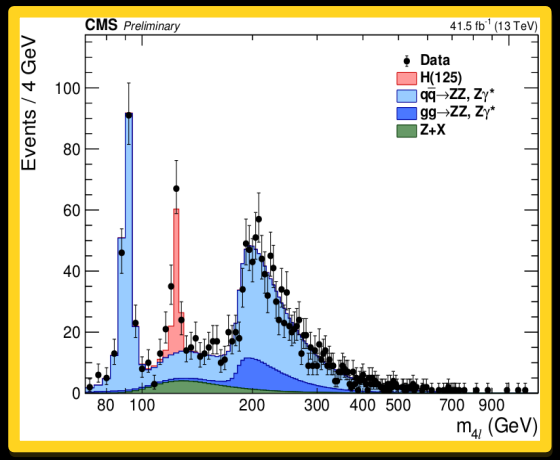
HIG-18-002



Using the on-shell and off-shell information of the 4ℓ final state

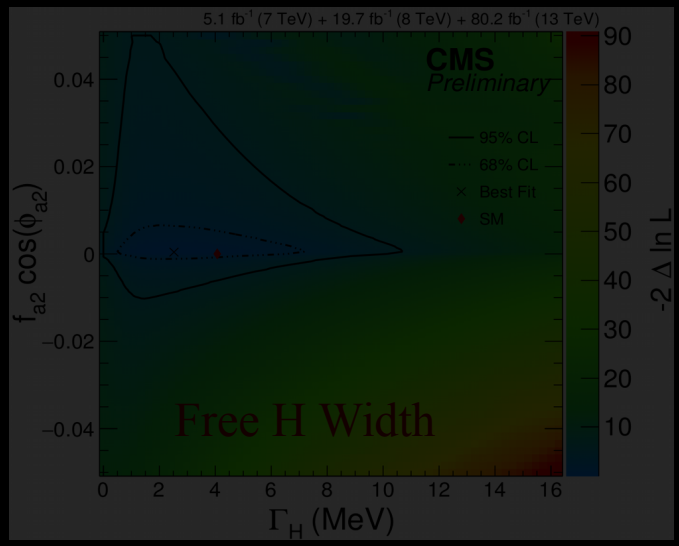


Higgs HVV anomalous couplings



CMS

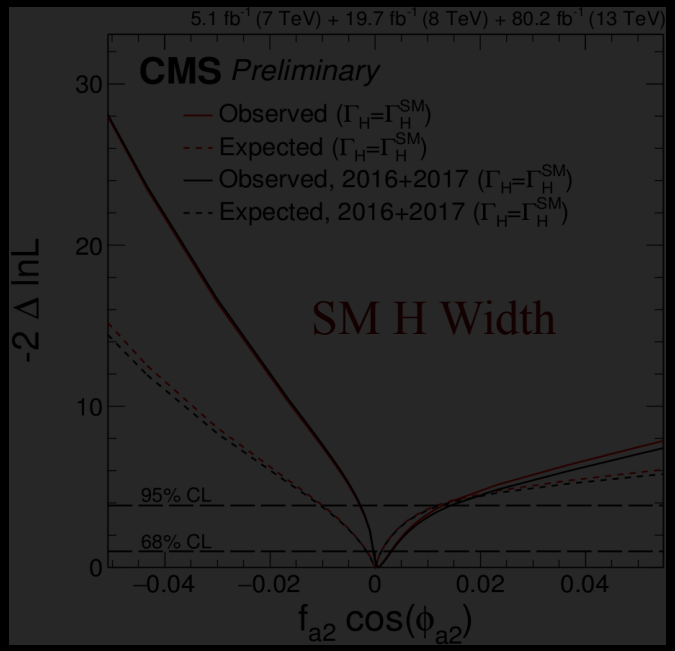
HIG-18-002



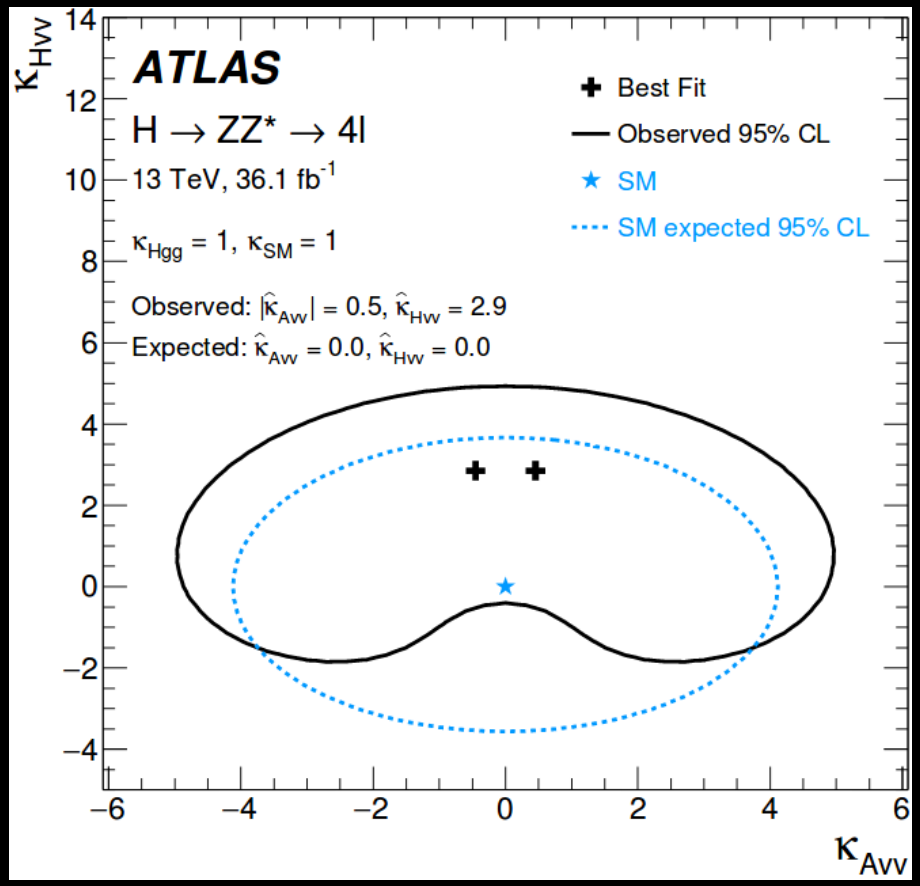
Using the on-shell and off-shell information of the 4ℓ final state

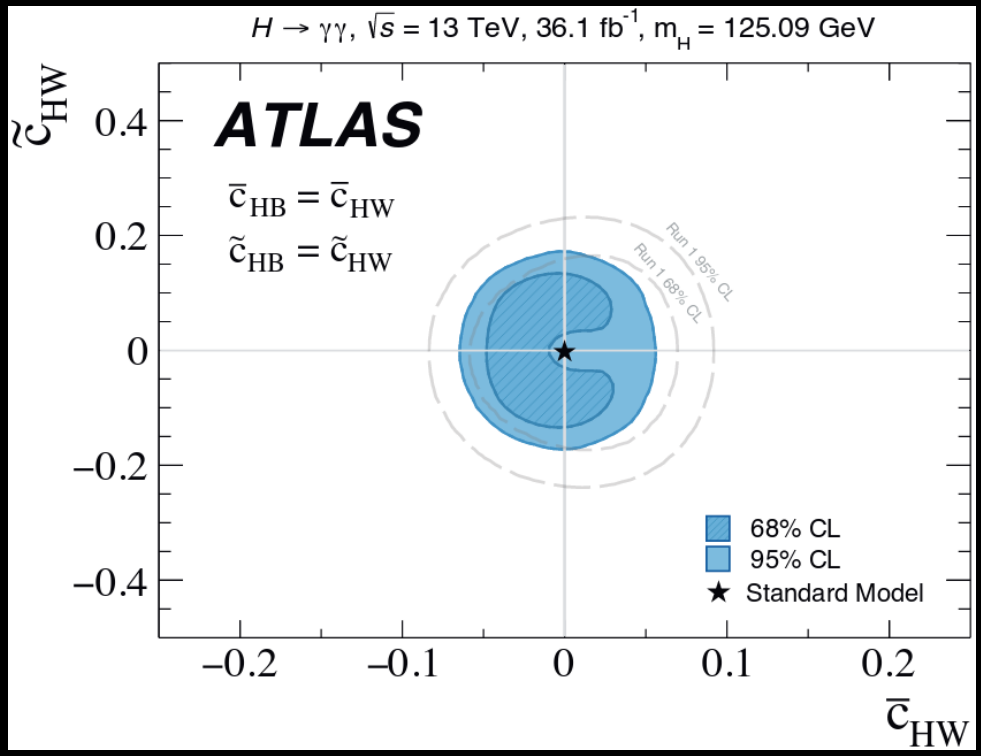
SM coupling

Parameter	Observed	Expected
Γ_H (MeV)	$3.2^{+2.8}_{-2.2}$ [0.08, 9.16]	$4.1^{+5.0}_{-4.0}$ [0.0, 13.7]



Higgs HVV anomalous couplings

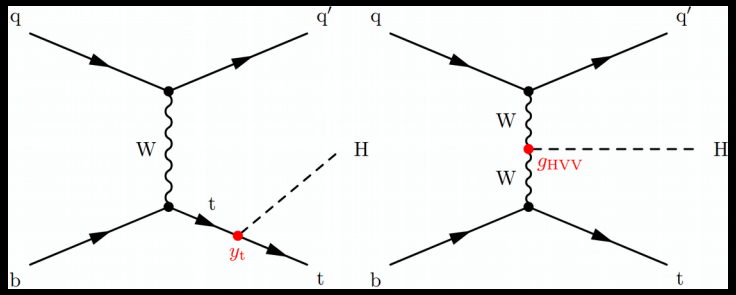




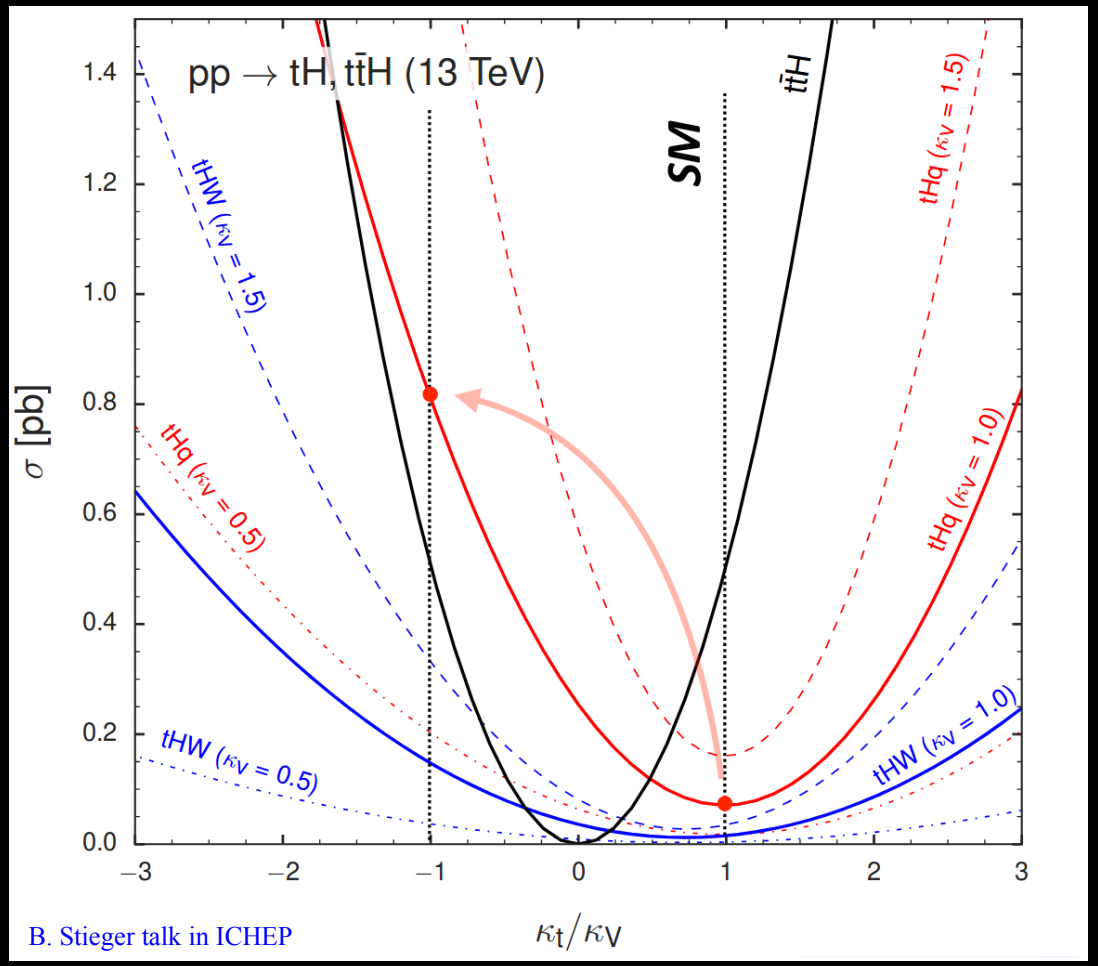
ATLAS EXPERIMENT JHEP 03 (2018) 095

ATLAS EXPERIMENT arXiv:1802.04146

Inverted top-H coupling



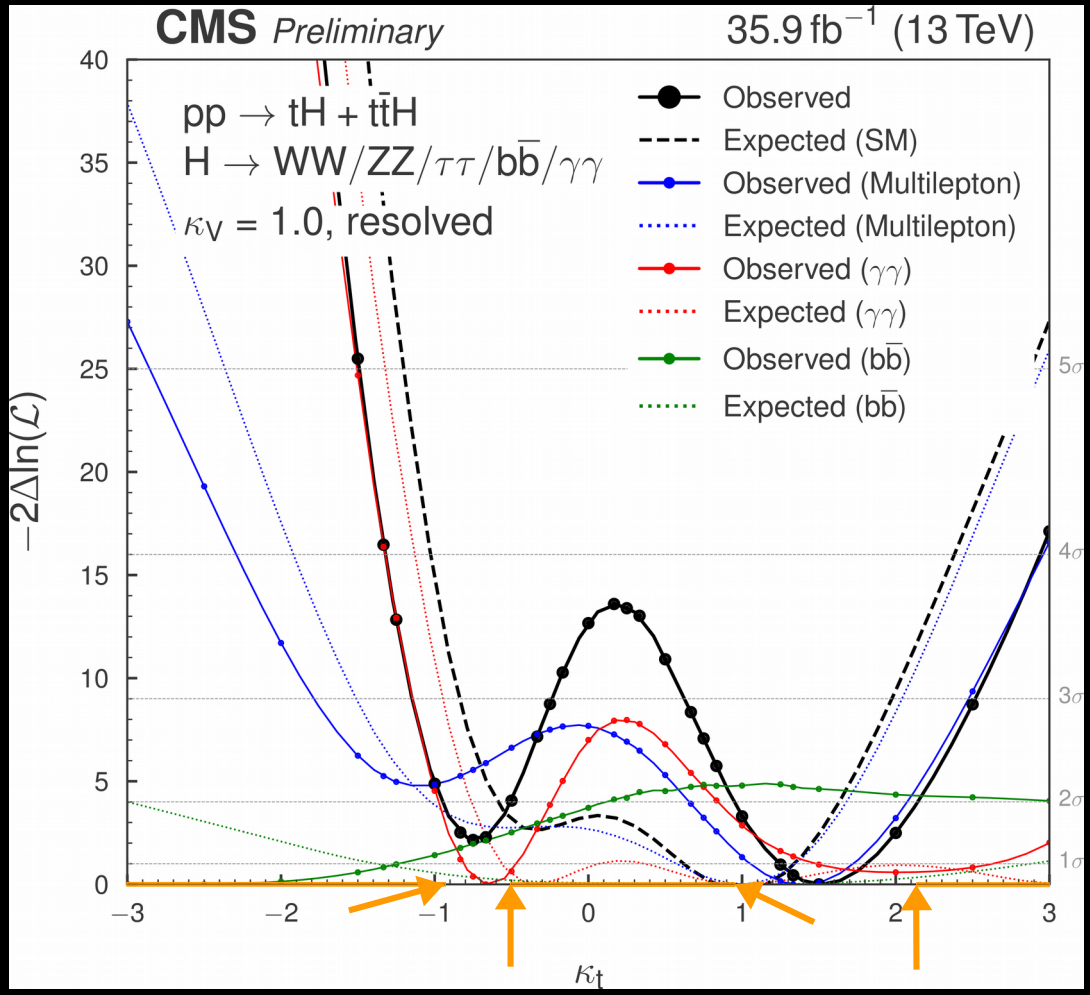
σ_{tHq} sensitive to amplitude, relative sign & phase of y_t and g_{HVV}.



κ: ratio of the coupling to SM

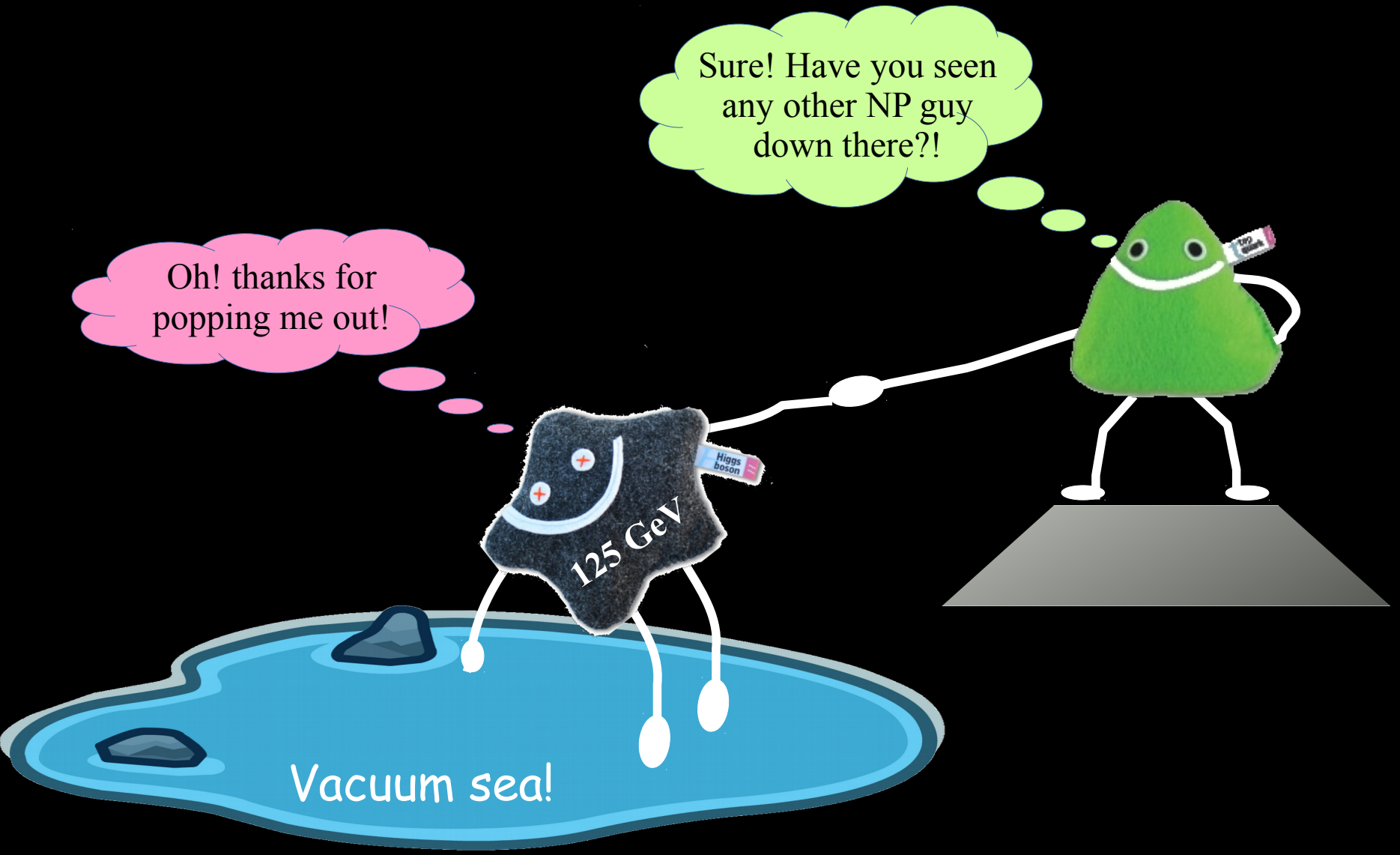
Inverted top-H coupling: tHq search

CMS-HIG-18-009



Inverted coupling is not entirely excluded!

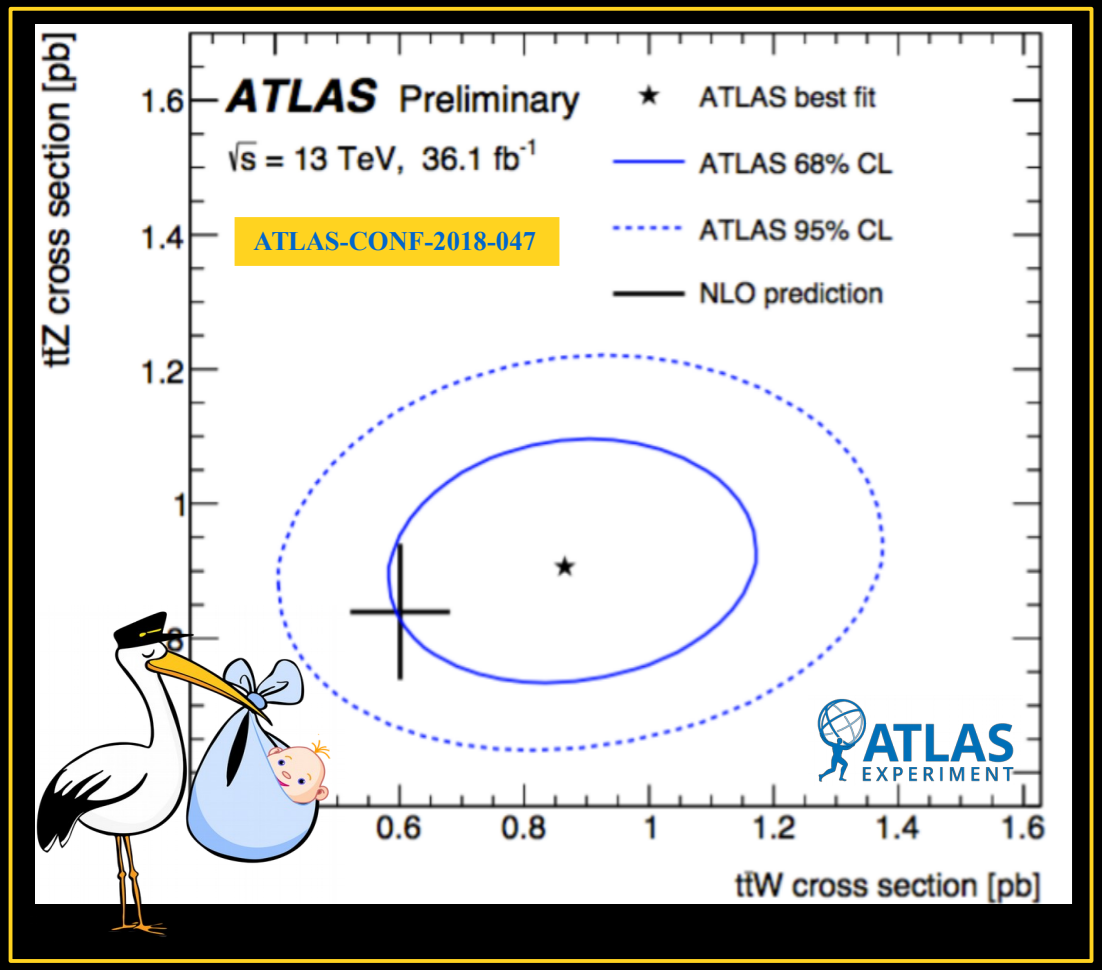
- Data constrain y_t to within [-0.9, -0.5] and [1.0, 2.1] times y_t^{SM}
- Slightly favor positive sign of y_t at about 1.5 σ

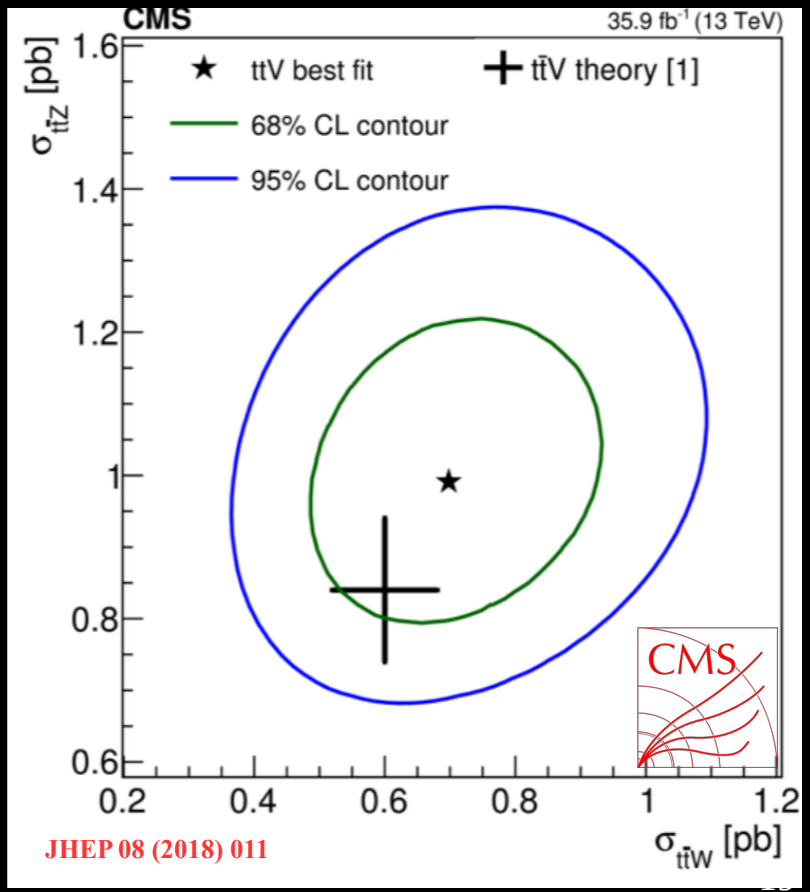

Sure! Have you seen any other NP guy down there?!
Oh! thanks for popping me out!
Higgs boson
125 GeV
Vacuum sea!

The top quark

- Very well established production in pair and in single mode!
- Looking for associated productions

Pair production+V

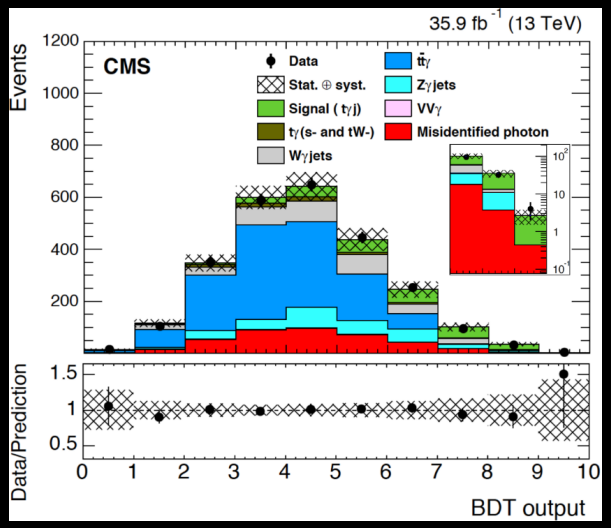




The top quark

- Very well established production in pair and in single mode!
- Looking for associated productions

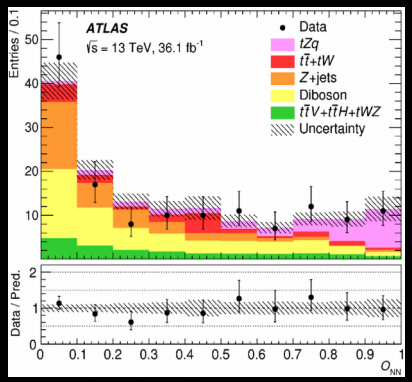
t + γ evidence



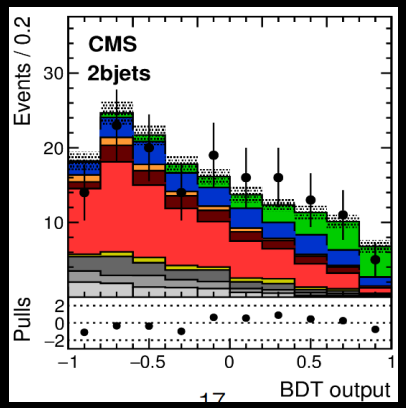
CMS

arXiv:1808.02913

t + Z evidence

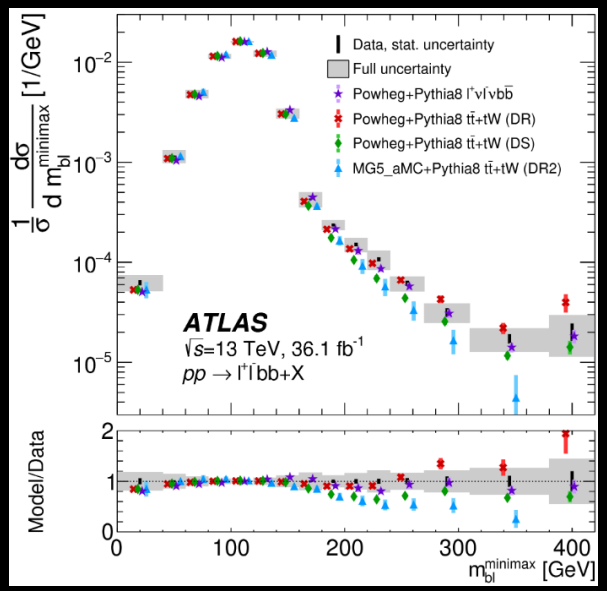


PLB 780 (2018) 557



PLB 779 (2018) 358

t + W modeling!

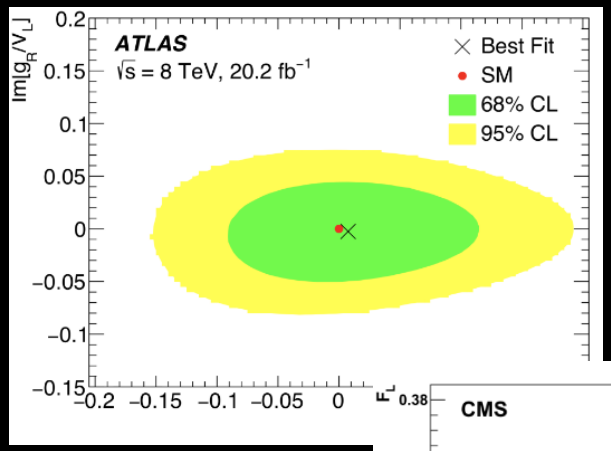


ATLAS EXPERIMENT

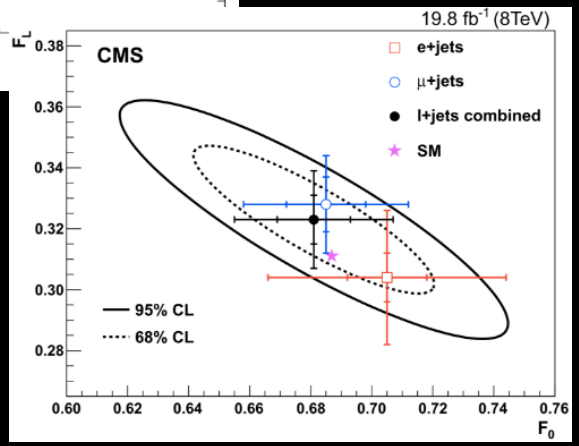
arXiv:1806.04667

The top quark

- Very well established production in pair and in single mode!
- Looking for associated productions
- Constraining BSM interactions …



3-angle analyses in single-top



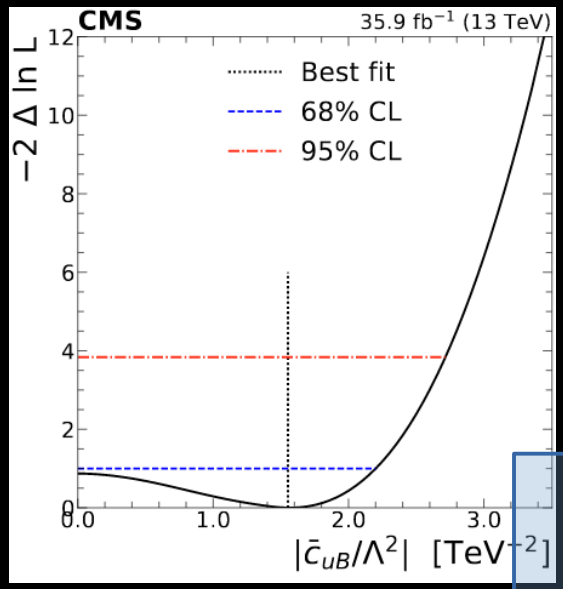
W-helicity in top pairs

Analyses designed to probe Wtb anomalous couplings

+ …

The top quark

- Very well established production in pair and in single mode!
- Looking for associated productions
- Constraining BSM interactions …



$t\bar{t}V$ production used to constrain EFT parameters

Coming soon!

ATLAS EXPERIMENT

The top quark

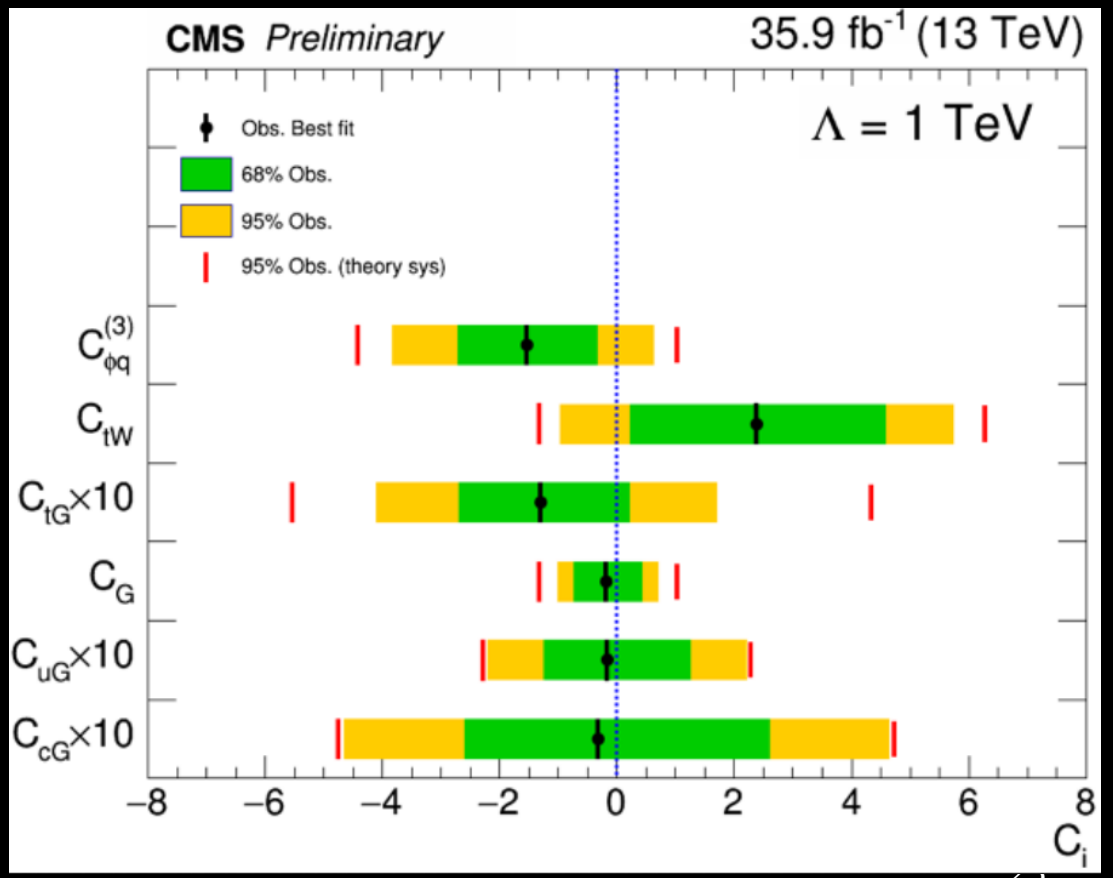
- Very well established production in pair and in single mode!
- Looking for associated productions
- Constraining BSM interactions ***beyond reinterpretation!***

New approach:
constrain EFT *directly* via **data**

The first global analysis of tW+tt

CMS

TOP-17-020



The top quark EFT

- So far, standalone measurements by experiments
- Theorists made the effort to collect & interpret all the results *globally*
- Experimentalists made their own EFT analyses per measurement

arXiv:1802.07237

Interpreting top-quark LHC measurements
in the standard-model effective field theory

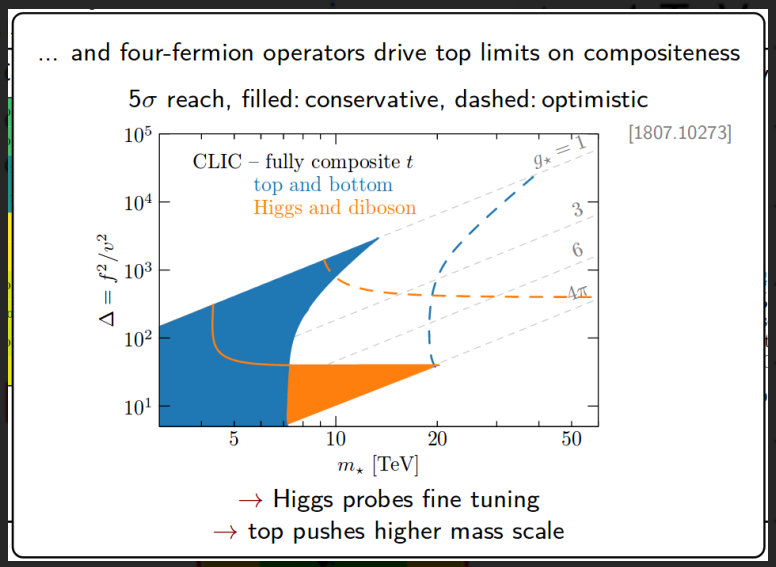
J. A. Aguilar Saavedra,[1] C. Degrande,[2] G. Durieux,[3]
F. Maltoni,[4] E. Vryonidou,[2] C. Zhang[5] (editors),
D. Barducci,[6] I. Brivio,[7] V. Cirigliano,[8] W. Dekens,[8,9] J. de Vries,[10] C. Englert,[11]
M. Fabbrichesi,[12] C. Grojean,[3,13] U. Haisch,[2,14] Y. Jiang,[7] J. Kamenik,[15,16]
M. Mangano,[2] D. Marzocca,[12] E. Mereghetti,[8] K. Mimasu,[4] L. Moore,[4] G. Perez,[17]
T. Plehn,[18] F. Riva,[2] M. Russell,[18] J. Santiago,[19] M. Schulze,[13] Y. Soreq,[20]
A. Tonero,[21] M. Trott,[7] S. Westhoff,[18] C. White,[22] A. Wulzer,[2,23,24] J. Zupan.[25]

This note proposes common standards and prescriptions for the effective-field-theory interpretation of top-quark measurements at the LHC.

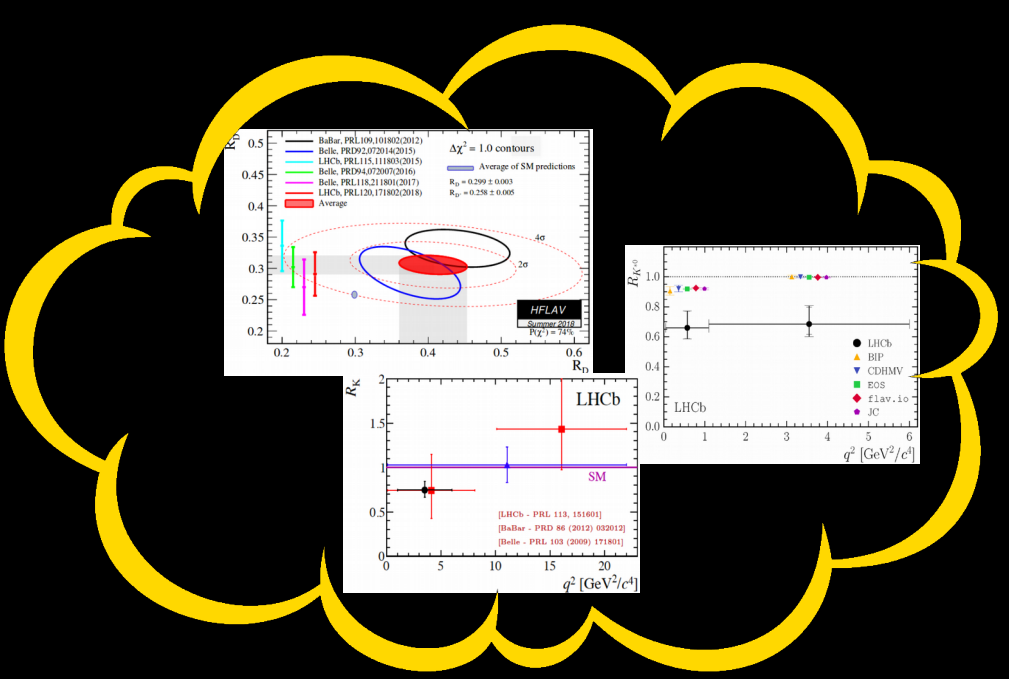
TOP-17-020

Towards a global EFT analysis including all necessary information, e.g. correlations

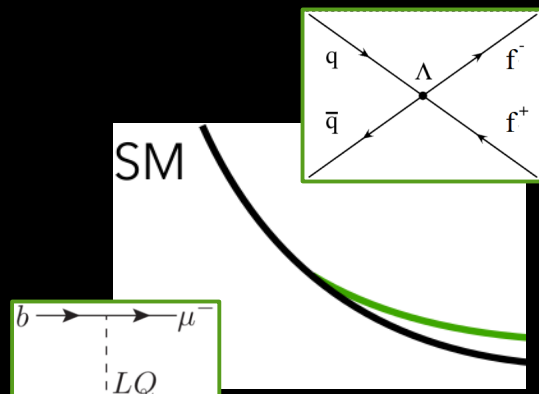
Example of global analysis in future colliders



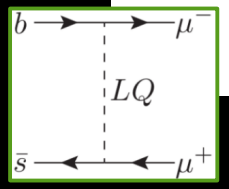
Future experiments could follow these common standards ...


BaBar, PRL109,101802(2012)
Belle, PRD92,072014(2015)
LHCb, PRL115,111803(2015)
Belle, PRD94,072007(2016)
Belle, PRL118,211801(2017)
LHCb, PRL120,171802(2018)
Average
$\Delta\chi^2 = 1.0$ contours
Average of SM predictions
$R_D = 0.299 \pm 0.003$
$R_{D^*} = 0.258 \pm 0.005$
HFLAV
Summer 2018
R_D
R_{D^*}
LHCb
SM
[LHCb - PRL 113, 151601]
[BaBar - PRD 86 (2012) 032012]
[Belle - PRL 103 (2009) 171801]
q^2 [GeV^2/c^4]
LHCb
BIP
CDHMV
EOS
flav.io
JC
q^2 [GeV^2/c^4]

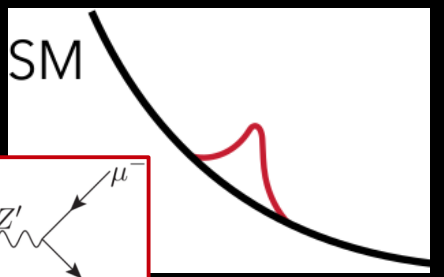
MARTIN

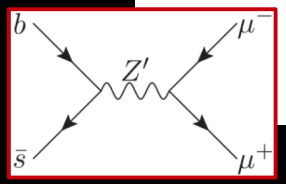

SM

q
$\bar{q}$
Λ
f^-
f^+


b
μ^-
LQ
$\bar{s}$
μ^+

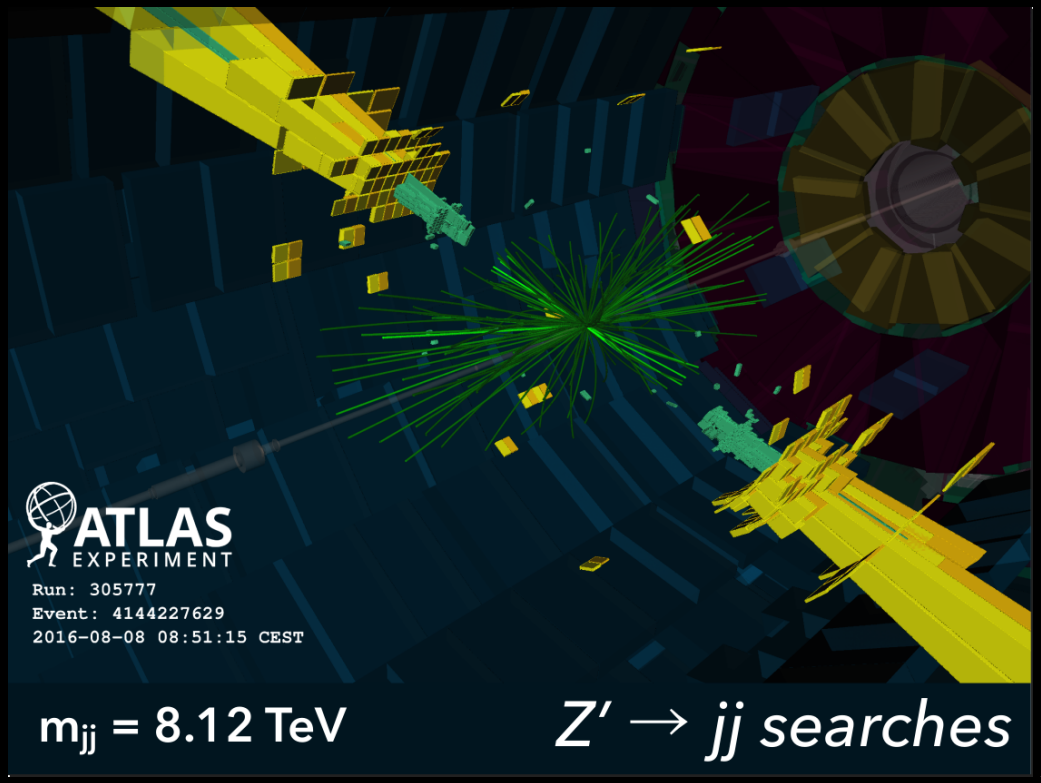
?

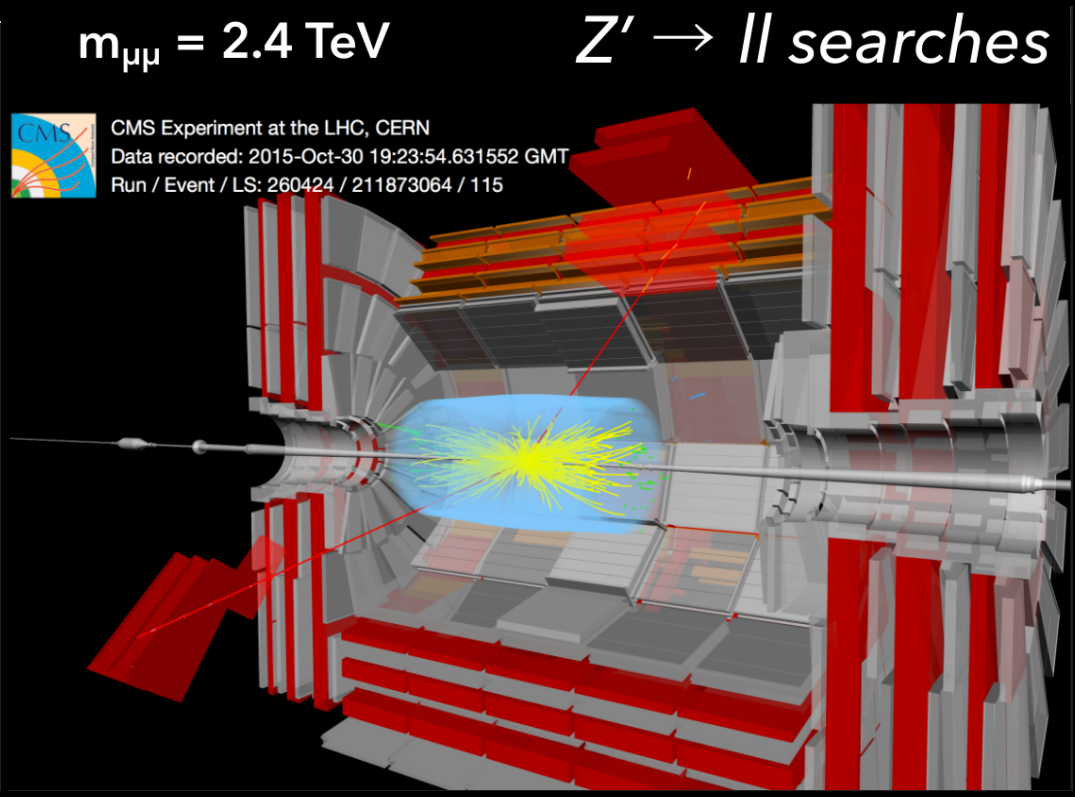

SM


b
μ^-
Z'
$\bar{s}$
μ^+

Searches for Z' and contact interactions

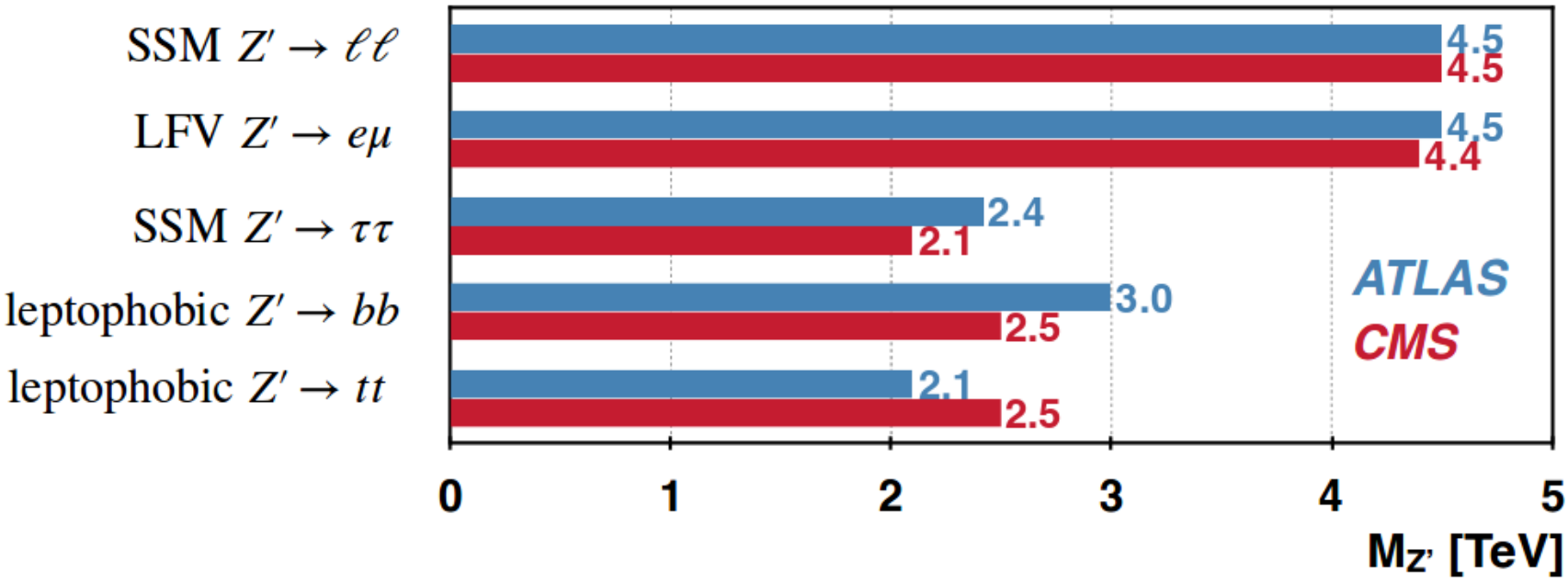
We saw some events here and there!

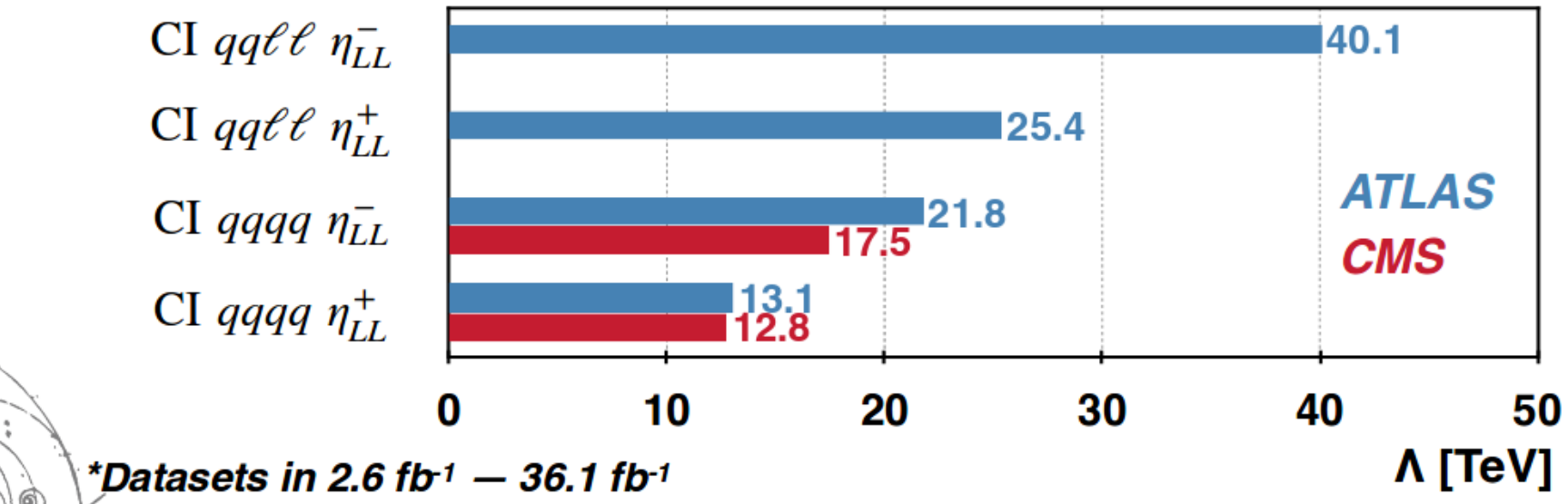




Not enough to claim a discovery …

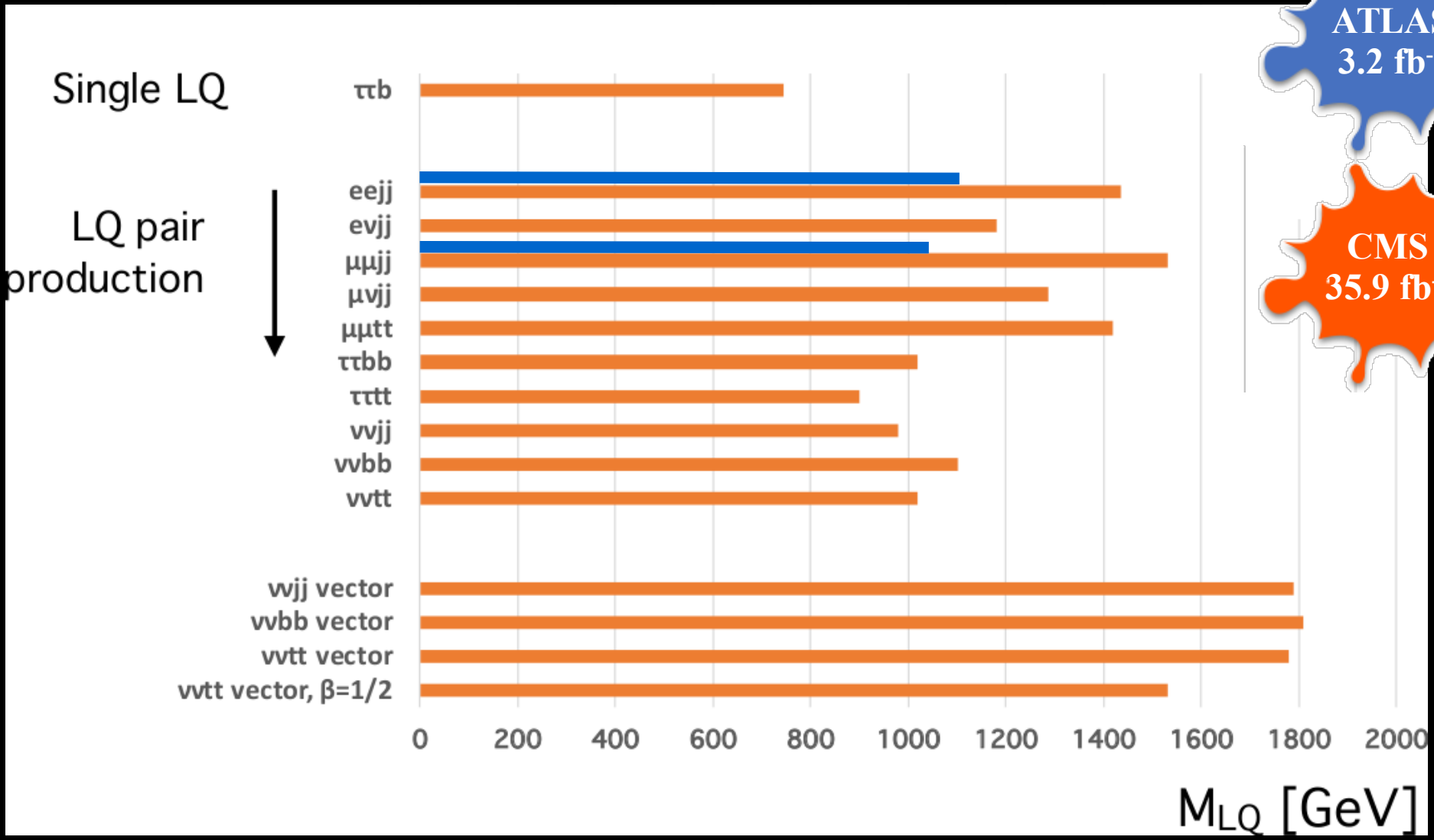
Summary: Run II benchmark observed limits*



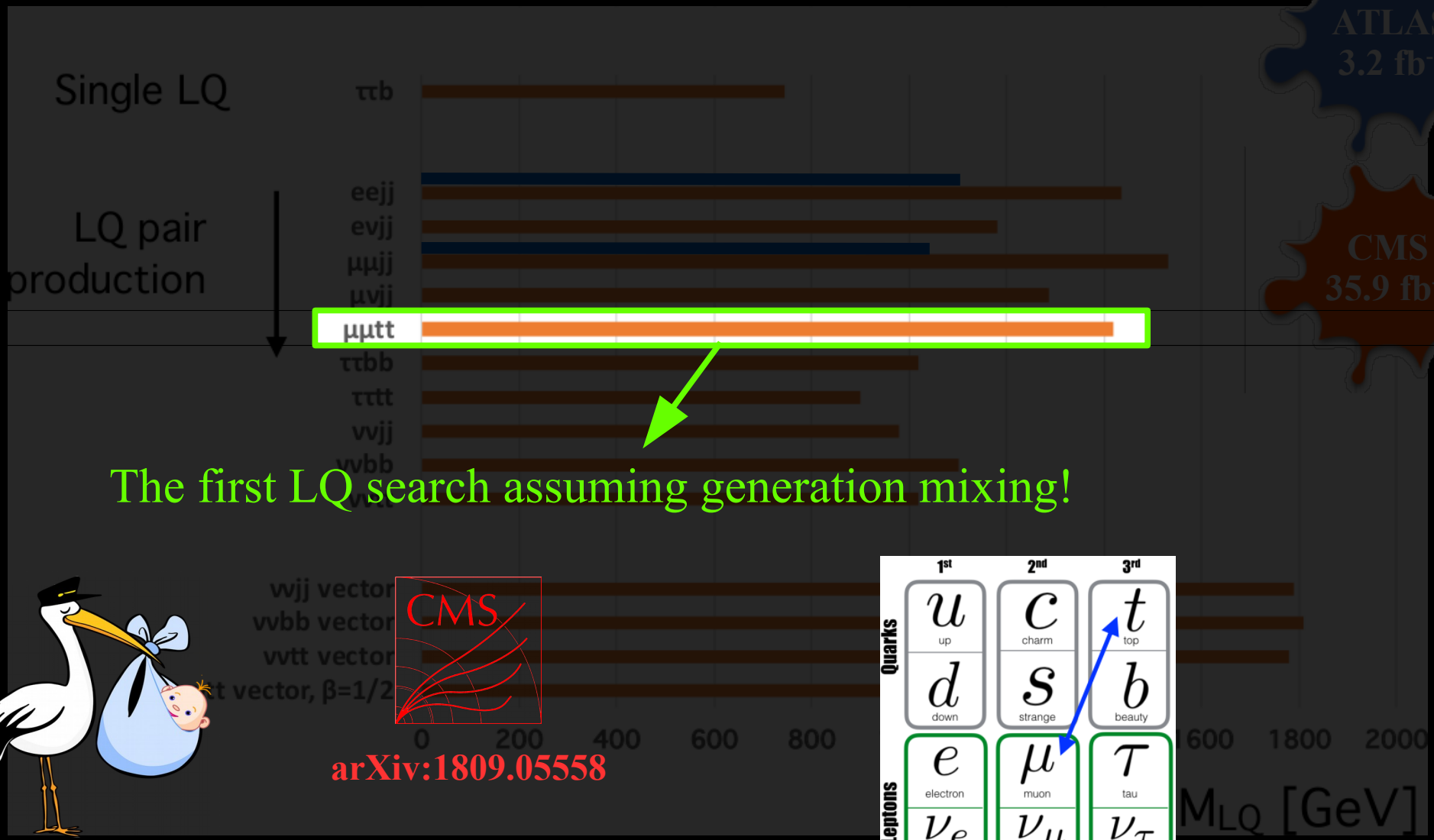


*Datasets in 2.6 fb^{-1} — 36.1 fb^{-1}

Searches for Letoquarks at 13 TeV



Searches for Letoquarks at 13 TeV

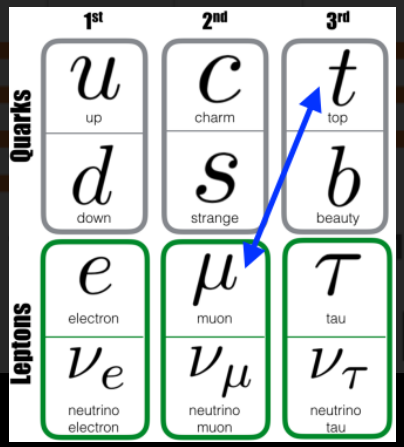


ATLAS 3.2 fb^{-1}

CMS 35.9 fb^{-1}

The first LQ search assuming generation mixing!

arXiv:1809.05558



LHC Run II

Energy++
$\sqrt{s}$ = ~~7,8~~ **13 TeV**

Luminosity++
~~30~~ **~140 fb^{-1}**

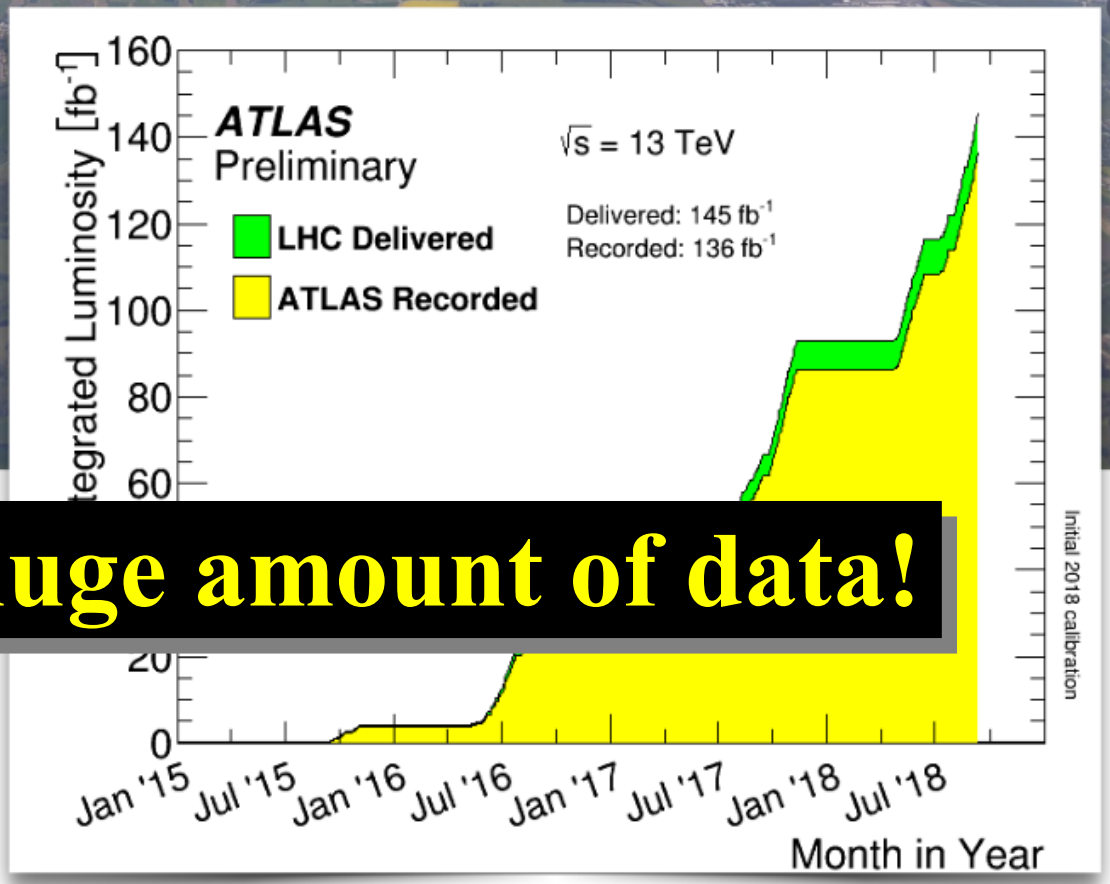
$$N_{obs} = \sigma \times A\epsilon \times \int Ldt$$

Trigger++
Reconstruction++

LHCb

ATLAS

CMS



We are collecting huge amount of data!

From E. Dreyer's talk

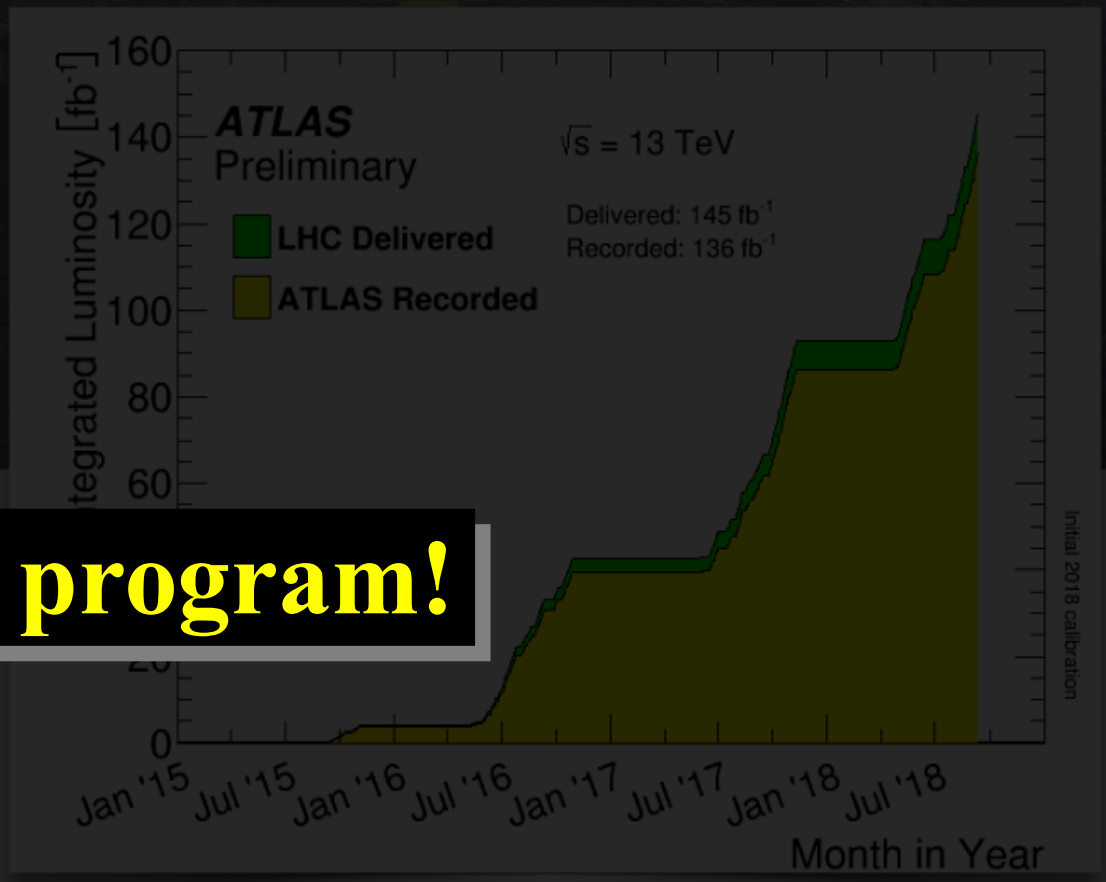
LHC Run II

Energy++
$\sqrt{s}$ = ~~7,8~~ **13 TeV**

Luminosity++
~~30~~ **~140 fb^{-1}**

$$N_{\text{obs}} = \sigma \times A\epsilon \times \int L dt$$

Trigger++
Reconstruction++



And a rich physics program!

From E. Dreyer's talk

LHC Run II

Energy++
$\sqrt{s}$ = ~~7,8~~ **13 TeV**

Luminosity++
~~30~~ **~140 fb^{-1}**

$$N_{\text{obs}} = \sigma \times A\epsilon \times \int Ldt$$

Trigger++
Reconstruction++

Still eagerly looking forward to ideas from theory colleagues!

From E. Dreyer's talk

BACKUP

ATLAS-CONF-2018-047

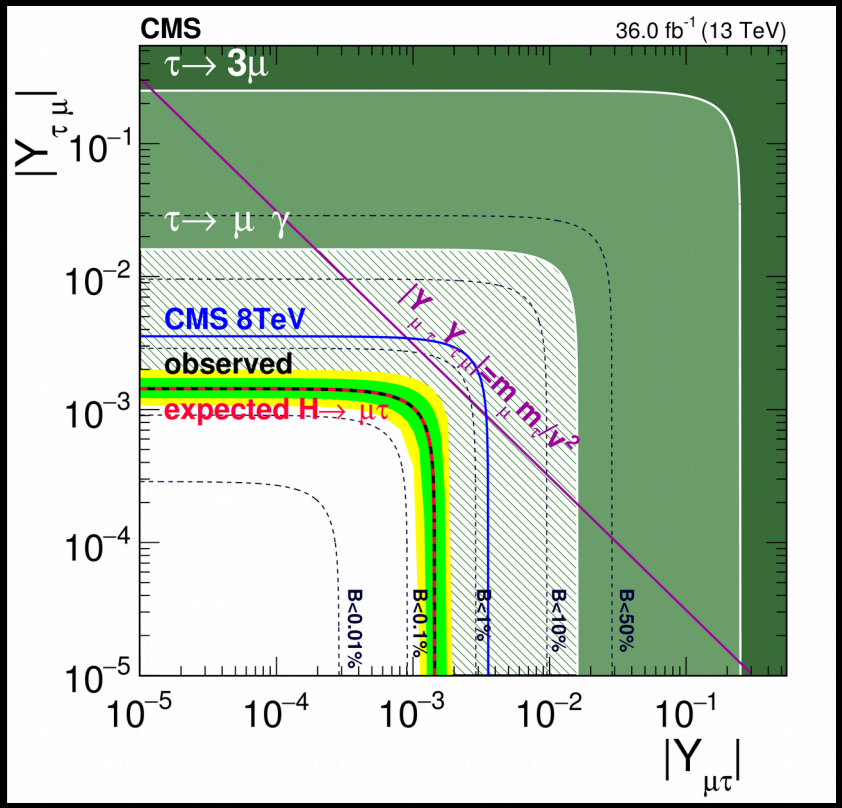
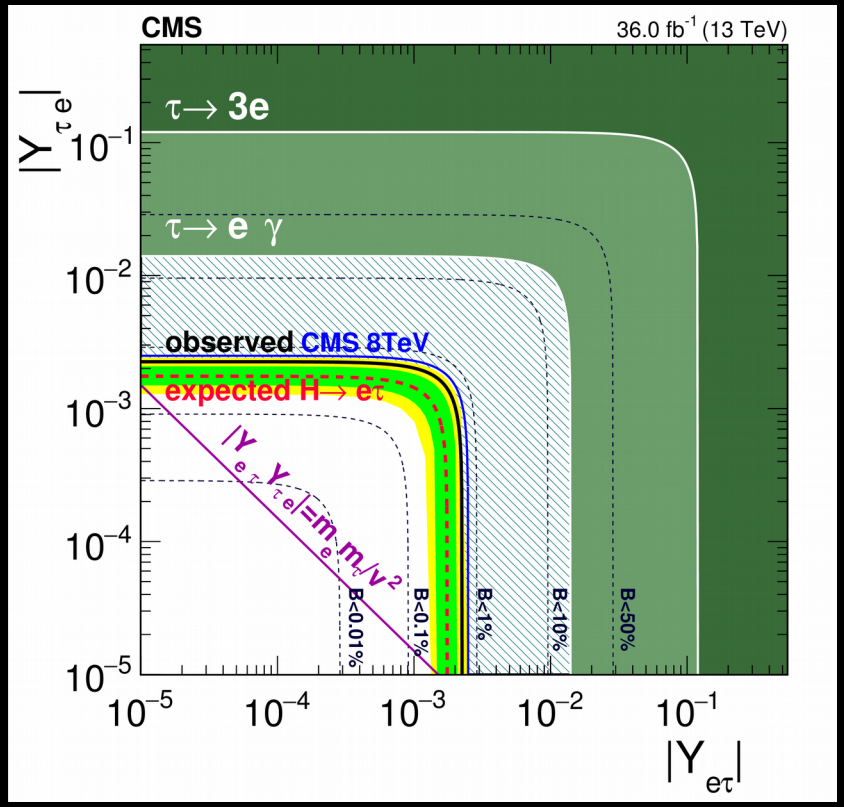
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Constraints on BSM

- Interpretations of the inclusive cross-section measurement in terms of Effective Field Theory (EFT).
  - Set constraints on the five operators which modify the ttZ vertex: $O_{\phi Q}^{(3)}$, $O_{\phi Q}^{(1)}$, $O_{\phi t}$, O_{tW}, O_{tB}
  - First two enter the ttZ vertex as a linear combination
    - measurement is sensitive to the difference: $C_{\phi Q}^{(3)} - C_{\phi Q}^{(1)}$
  - Only one operator is considered at a time.

Coefficient	Expected limits at 68% and 95 % CL	Observed limits at 68% and 95 % CL	Previous constraints at 95 % CL JHEP **05** (2016) 052
$(C_{\phi Q}^{(3)} - C_{\phi Q}^{(1)})/\Lambda^2$	[-2.1, 1.9], [-4.6, 3.7]	[-1.0, 2.7], [-3.4, 4.3]	[-3.4, 7.5]
$C_{\phi t}/\Lambda^2$	[-3.8, 2.8], [-23, 5.0]	[-2.0, 3.6], [-27, 5.7]	[-2.0, 5.7]
C_{tB}/Λ^2	[-8.3, 8.6], [-12, 13]	[-11, 10], [-15, 15]	[-16, 43]
C_{tW}/Λ^2	[-2.8, 2.8], [-4.0, 4.1]	[-2.2, 2.5], [-3.6, 3.8]	[-0.15, 1.9]

units of 1/TeV²

Lepton Flavor Violating Higgs decays

JHEP 06 (2018) 001