The Higgs, gauge bosons, and top quark at LHC

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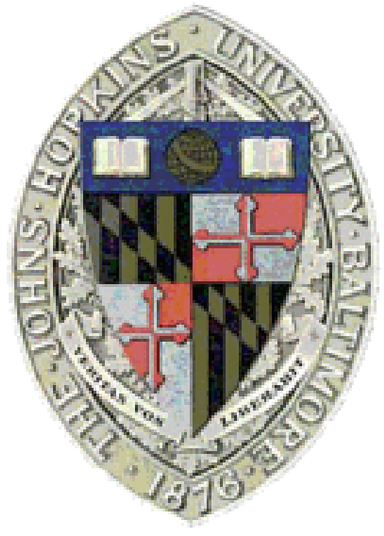
for the ATLAS and CMS experiments

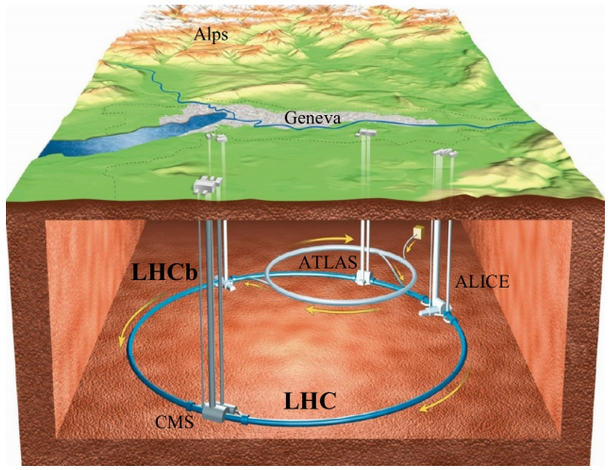


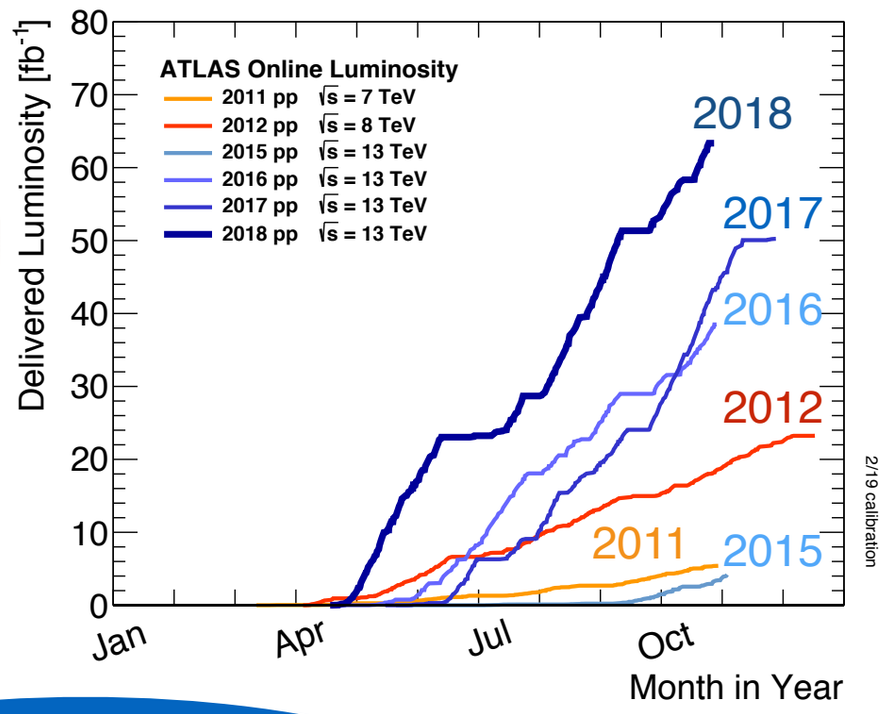
May 6, 2019

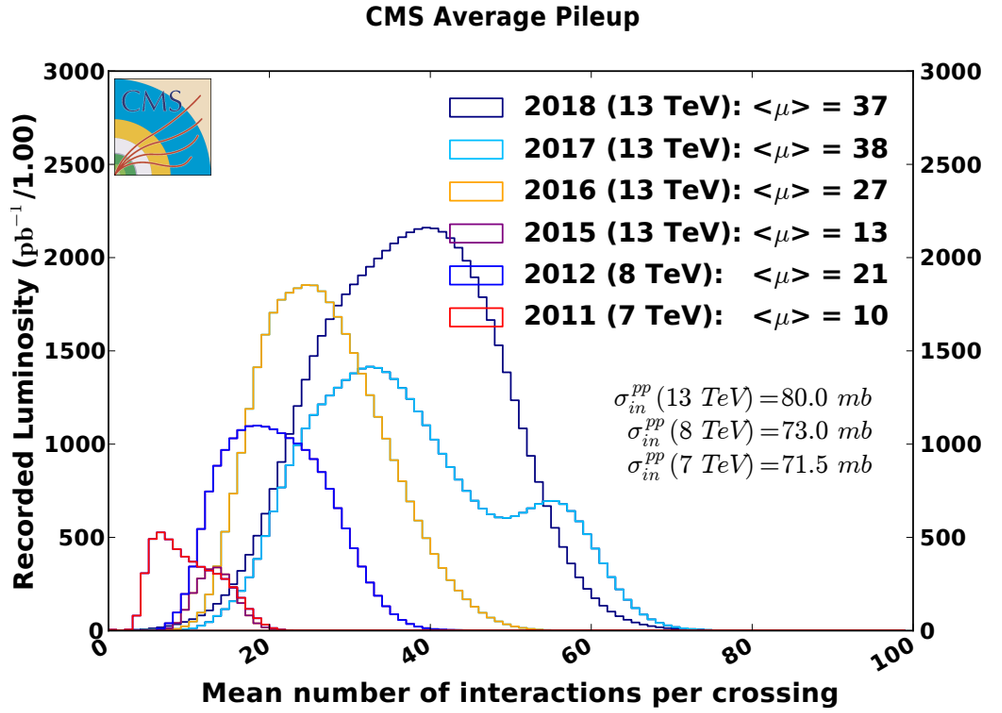
Phenomenology Symposium

University of Pittsburgh

LHC: Focus on Run-2 (and the next 20 years)

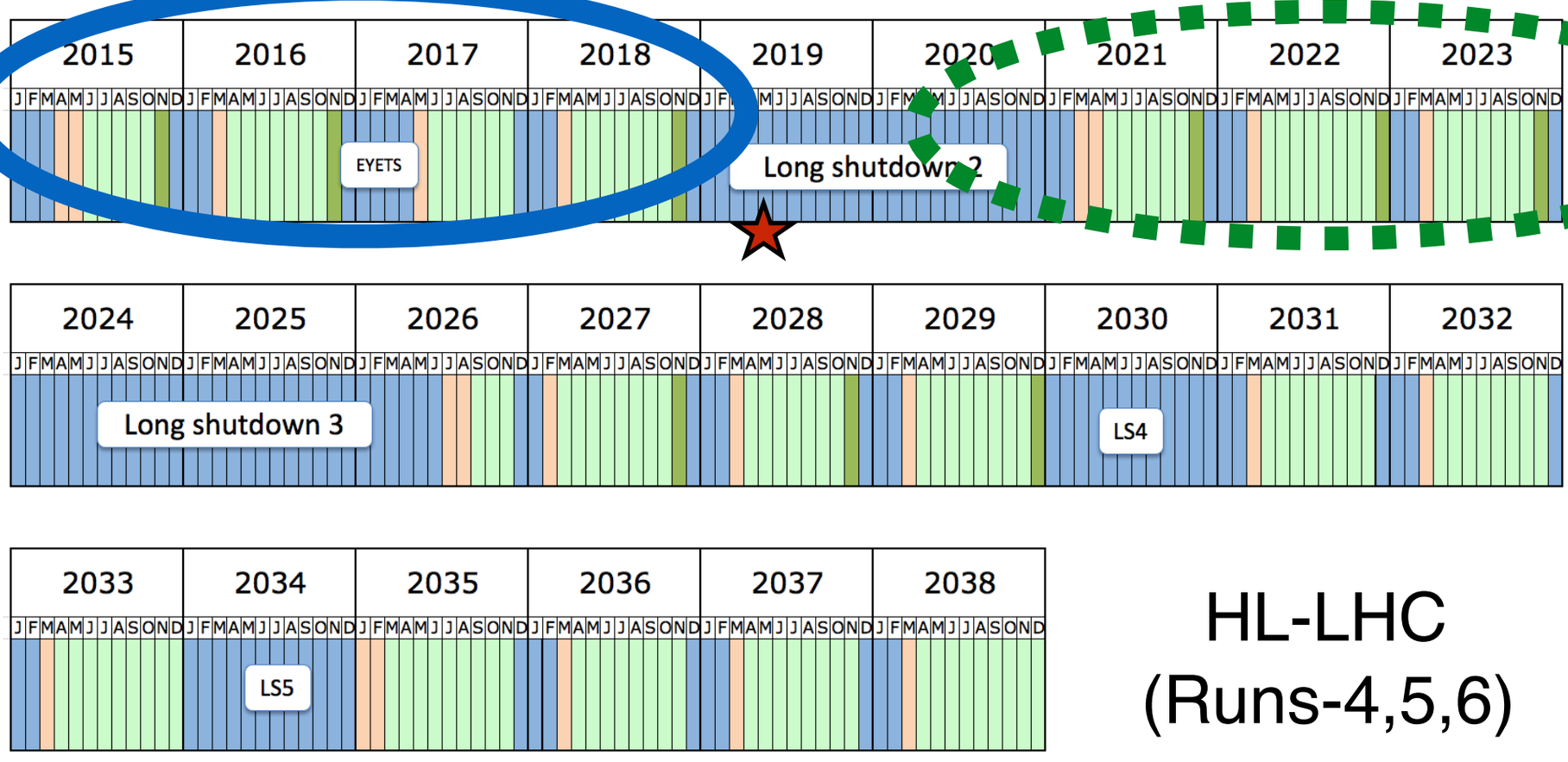






~140 fb^{-1}
at 13 TeV

Run-2



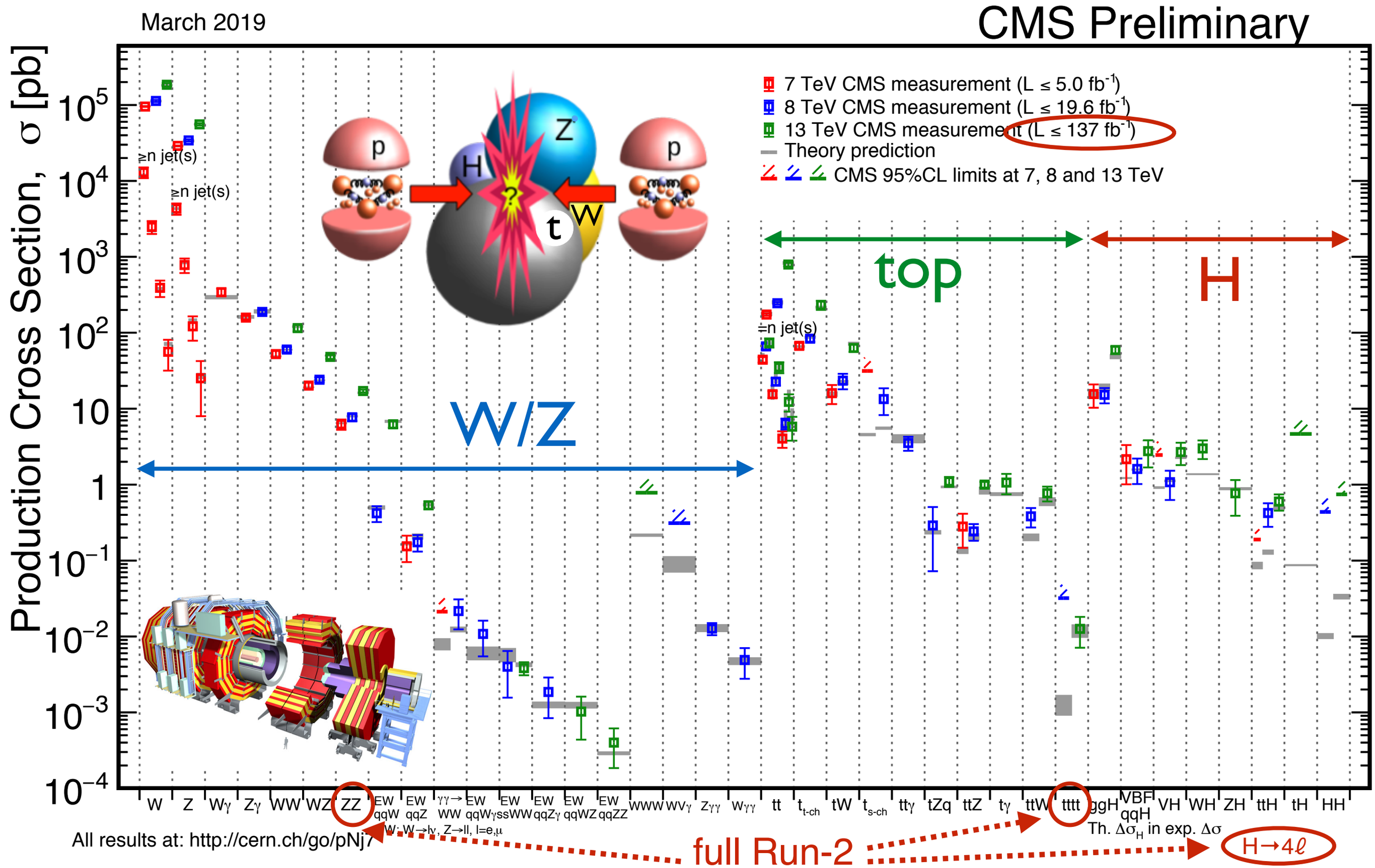
Run-3

expect
>200 fb^{-1}
at 13-14 TeV

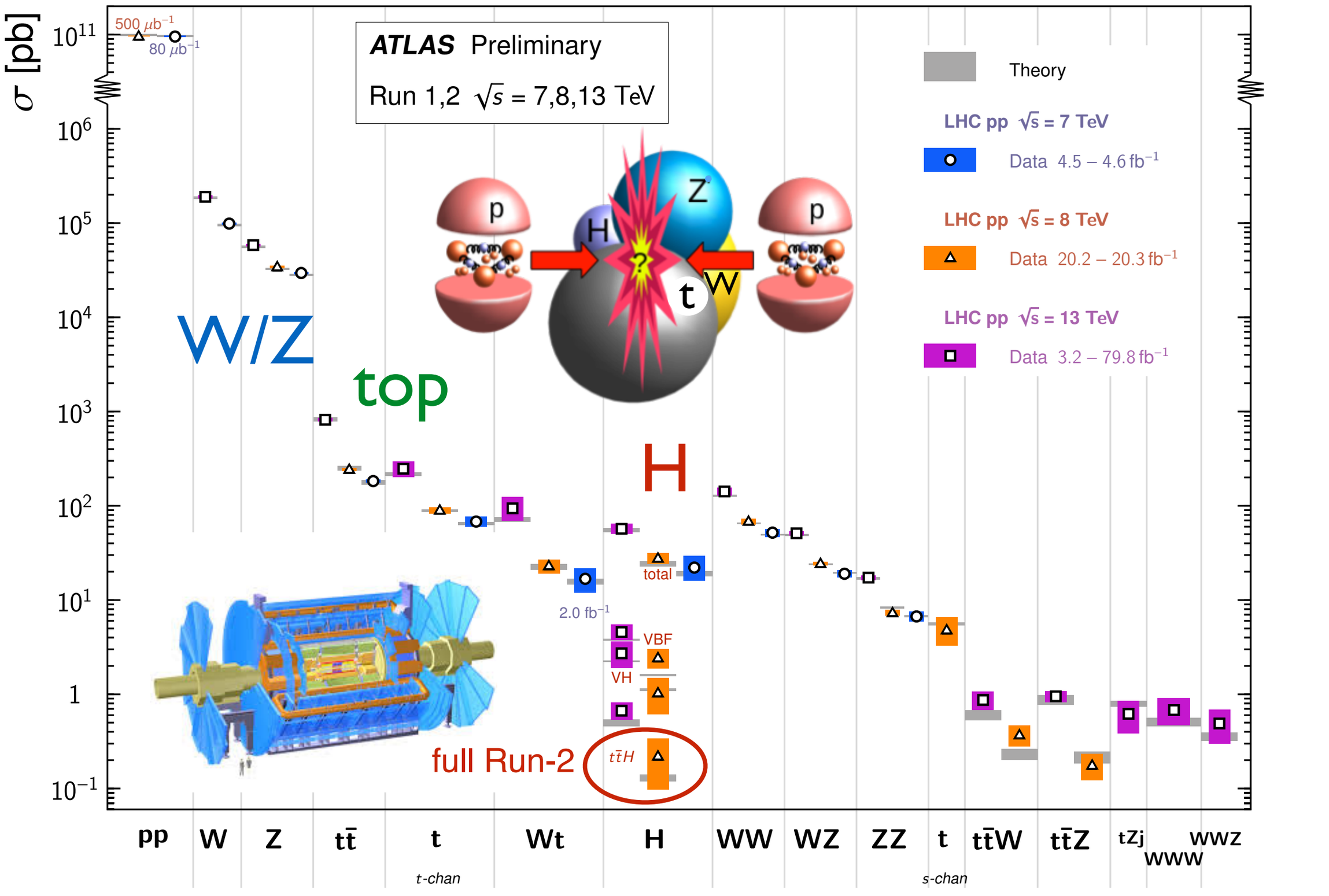
HL-LHC
(Runs-4,5,6)

expect
>3000 fb^{-1}

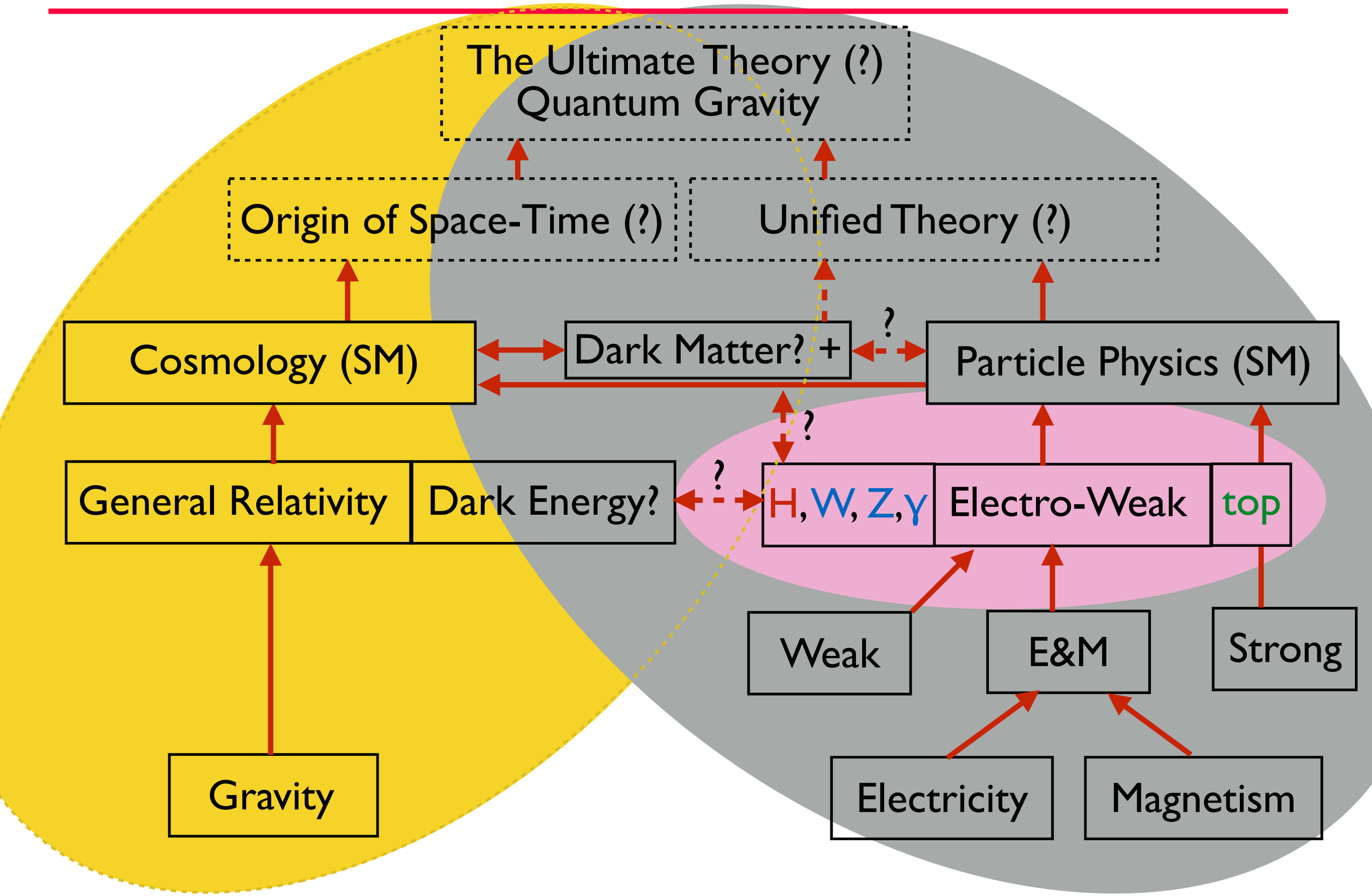
CMS: a bird's-eye view on the W/Z, top, H



ATLAS: a bird's-eye view on the W/Z, top, H



H, W/Z, top: the big picture view



H^0, W/Z, top: the PDG view

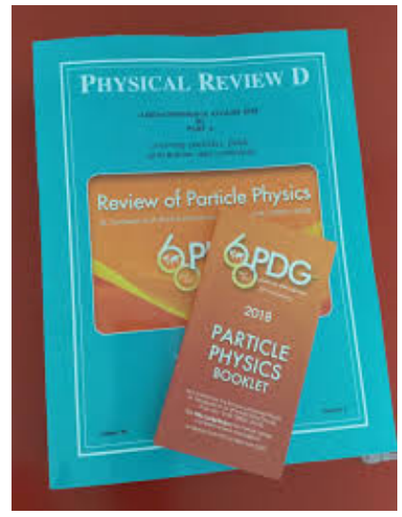
PDG particle data group — pdg.lbl.gov (2018) — Reviews, Tables, and Plots

— mass

— width / lifetime

— quantum numbers

— coupling strength



H^0

$J = 0$

Mass $m = 125.18 \pm 0.16$ 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 $= 1.10 \pm 0.11$
$WW^* = 1.08^{+0.18}_{-0.16}$
$ZZ^* = 1.14^{+0.15}_{-0.13}$
$\gamma\gamma = 1.16 \pm 0.18$
$b\bar{b} = 0.95 \pm 0.22$
$\mu^+\mu^- = 0.0 \pm 1.3$
$\tau^+\tau^- = 1.12 \pm 0.23$
$Z\gamma < 6.6$, CL = 95%
$t\bar{t}H^0$ Production $= 2.3^{+0.7}_{-0.6}$

t

$I(J^P) = 0(\frac{1}{2}^+)$

Charge $= \frac{2}{3}\ e$ Top $= +1$

Mass (direct measurements) $m = 173.0 \pm 0.4$ GeV [a,b] (S = 1.3)
Mass (from cross-section measurements) $m = 160^{+5}_{-4}$ GeV [a]
Mass (Pole from cross-section measurements) $m = 173.1 \pm 0.9$ GeV
$m_t - m_{\bar{t}} = -0.16 \pm 0.19$ GeV
Full width $\Gamma = 1.41^{+0.19}_{-0.15}$ GeV (S = 1.4)
$\Gamma(Wb)/\Gamma(Wq(q = b, s, d)) = 0.957 \pm 0.034$ (S = 1.5)

W

$J = 1$

Charge $= \pm 1\ e$
Mass $m = 80.379 \pm 0.012$ GeV
W/Z mass ratio $= 0.88153 \pm 0.00017$
$m_Z - m_W = 10.803 \pm 0.015$ GeV
$m_{W^+} - m_{W^-} = -0.029 \pm 0.028$ GeV
Full width $\Gamma = 2.085 \pm 0.042$ GeV

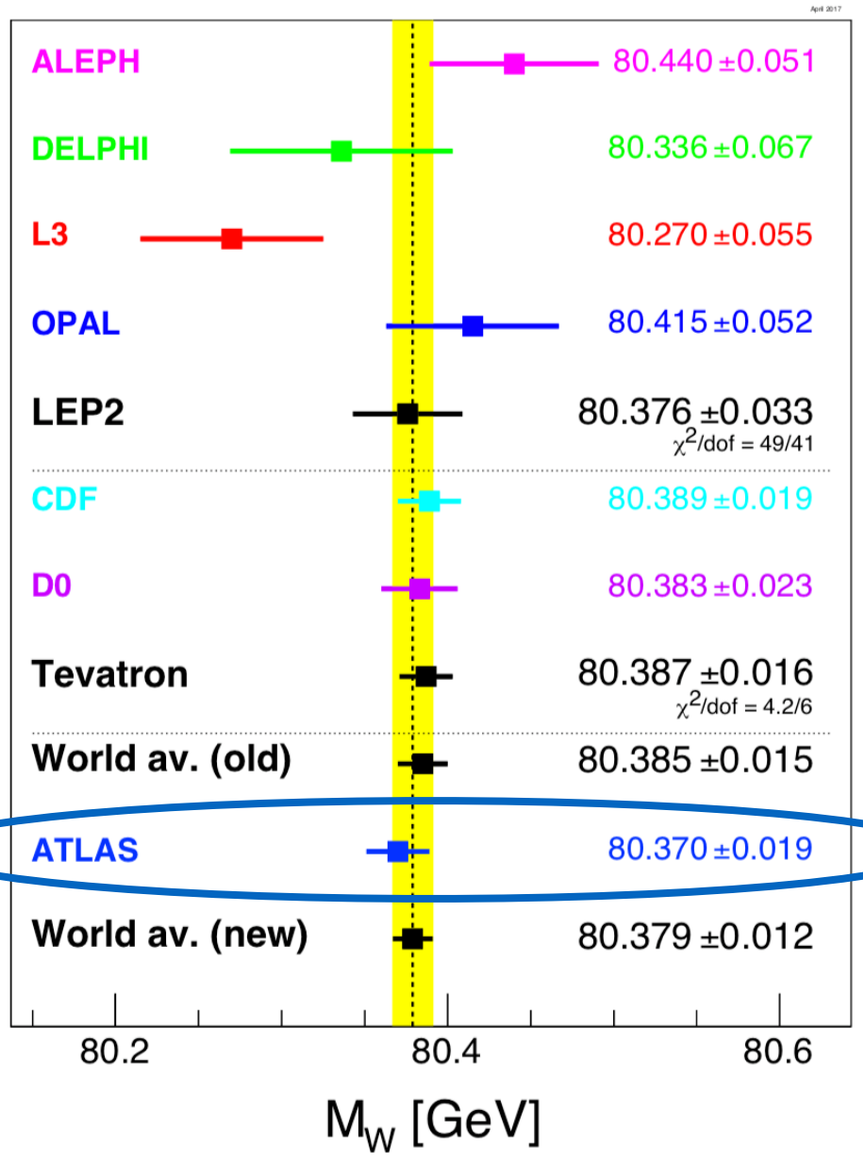
Z

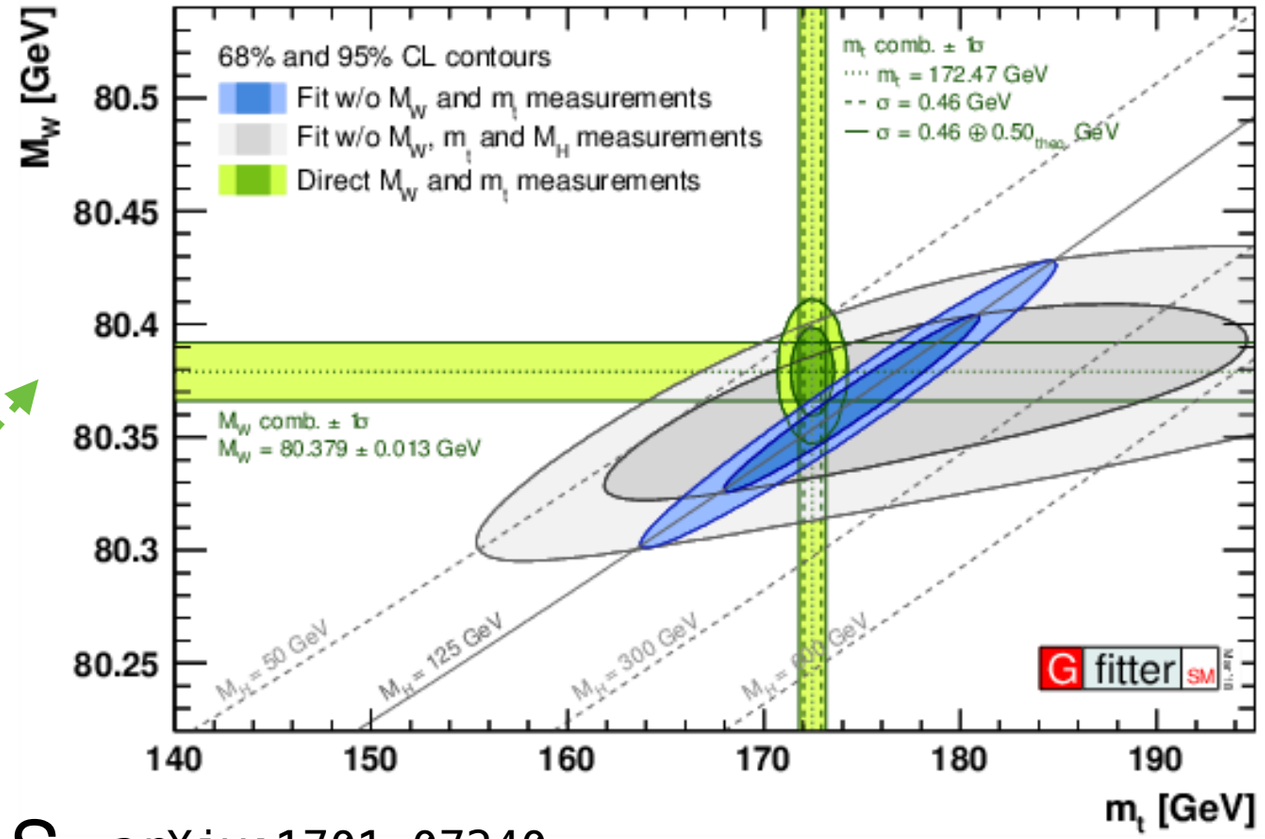
$J = 1$

Charge $= 0$
Mass $m = 91.1876 \pm 0.0021$ GeV [d]
Full width $\Gamma = 2.4952 \pm 0.0023$ GeV
$\Gamma(\ell^+\ell^-) = 83.984 \pm 0.086$ MeV [b]
Γ(invisible) $= 499.0 \pm 1.5$ MeV [e]
Γ(hadrons) $= 1744.4 \pm 2.0$ MeV

H, W/Z, top: the mass

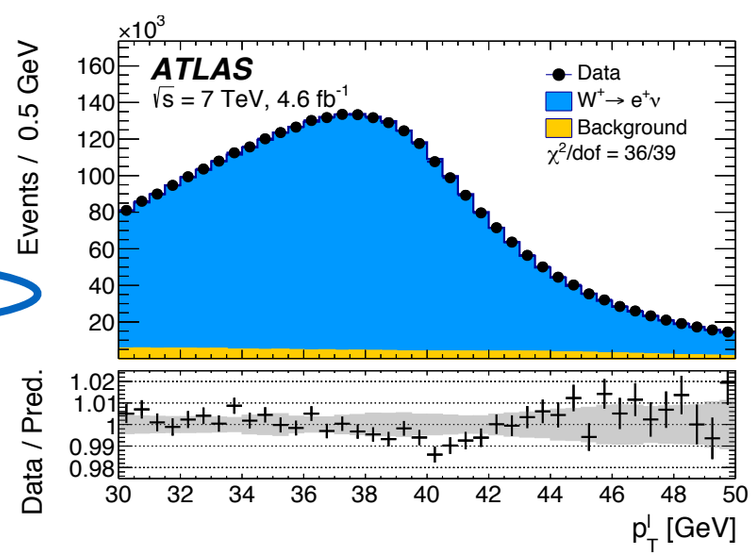
- the heaviest fundamental SM particles: m_H, m_W, m_t
  - — fundamental parameters
  - — over-constrain SM

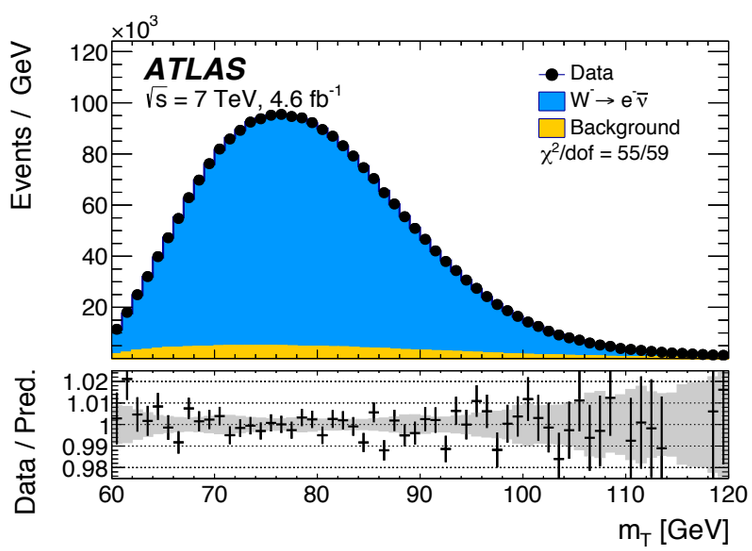




ATLAS arXiv:1701.07240

m_W = 80370 ±7 (stat.) ±11 (exp. syst.) ±14 (mod. syst.) MeV



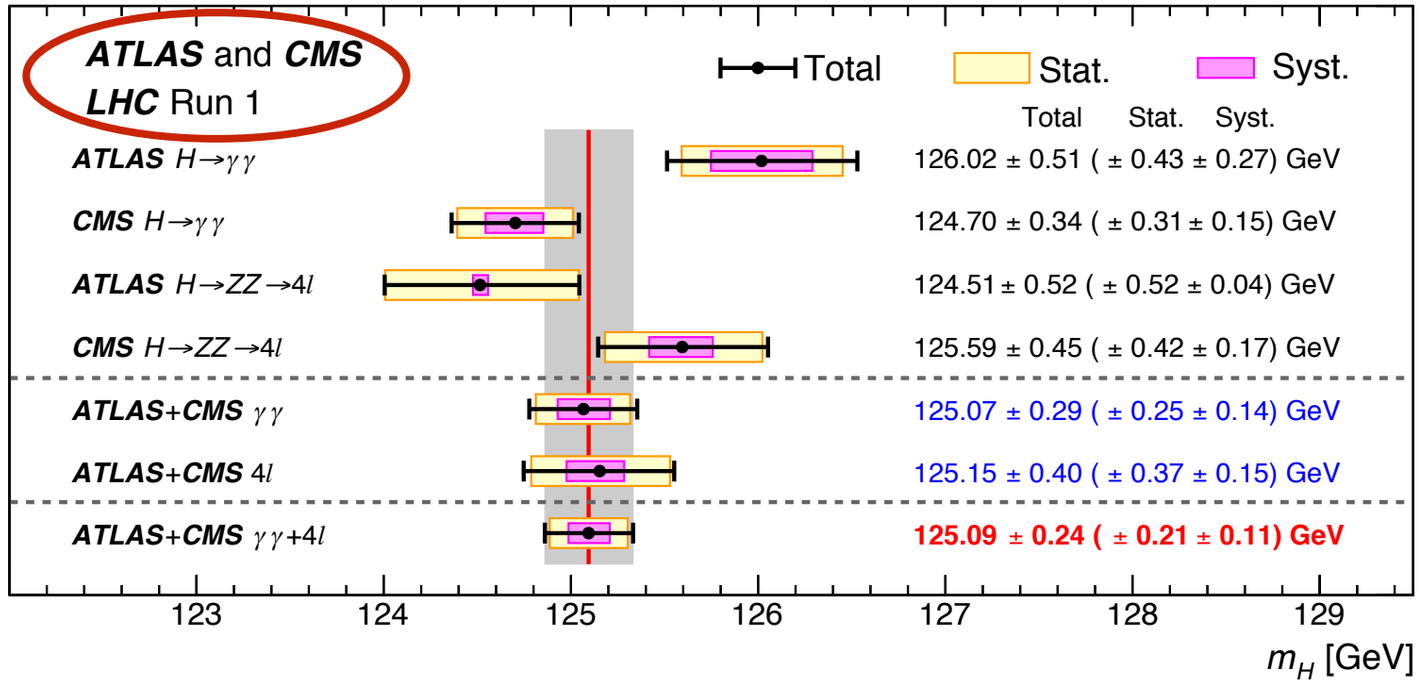


H: the mass

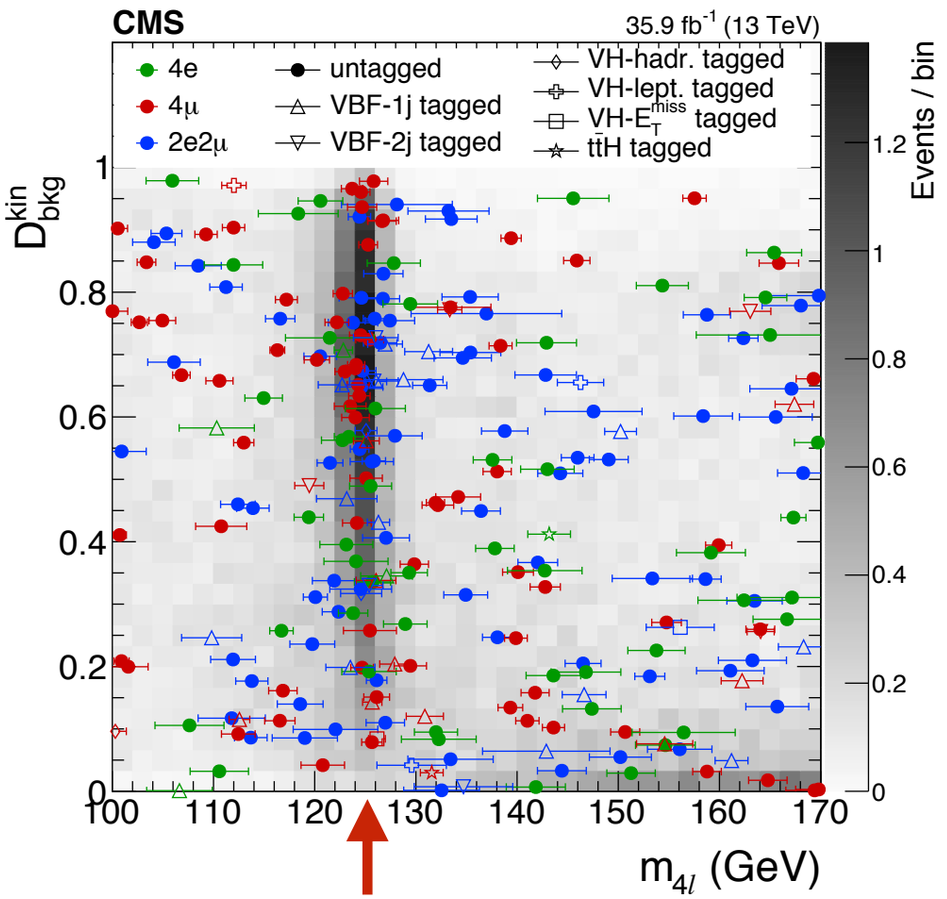
- H(125) mass (PDG-2018):

  $m_H = 125.18 \pm 0.16$ GeV

  LHC Run-1 + CMS 2016

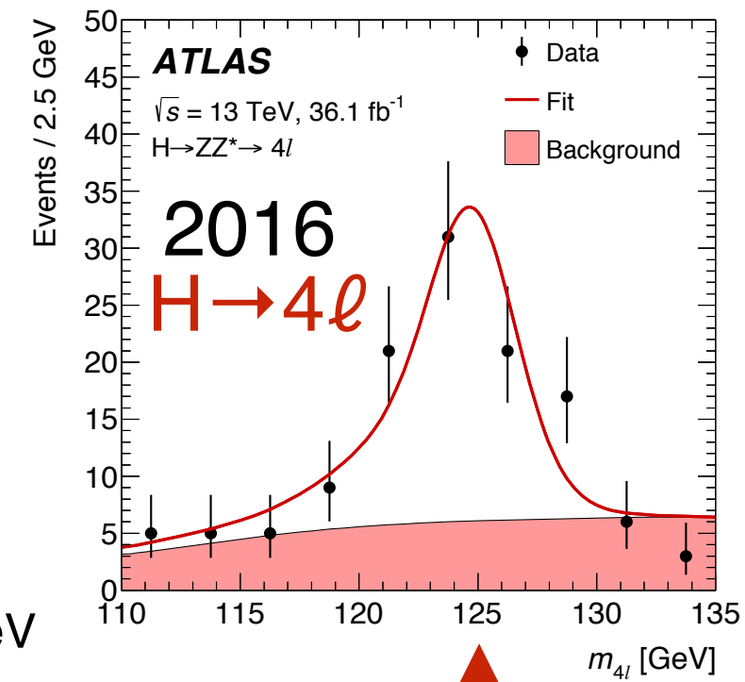


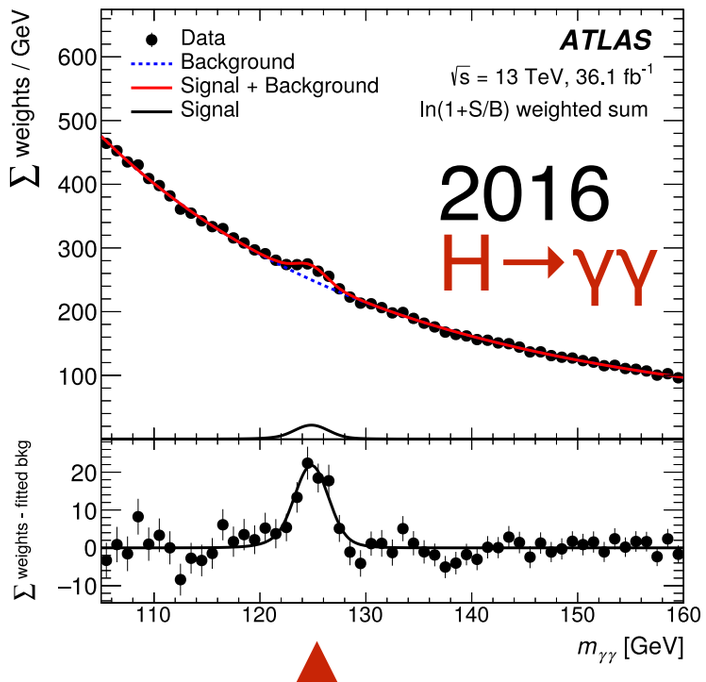
CMS 2016 arXiv:1706.09936 H→4ℓ



2016: $m_H = 125.26 \pm 0.20(\text{stat}) \pm 0.08(\text{syst})$ GeV

ATLAS 2015+2016 arXiv:1806.00242

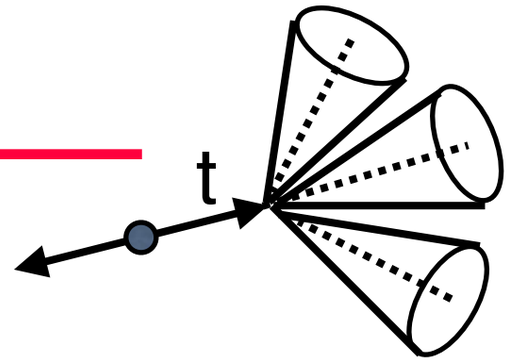




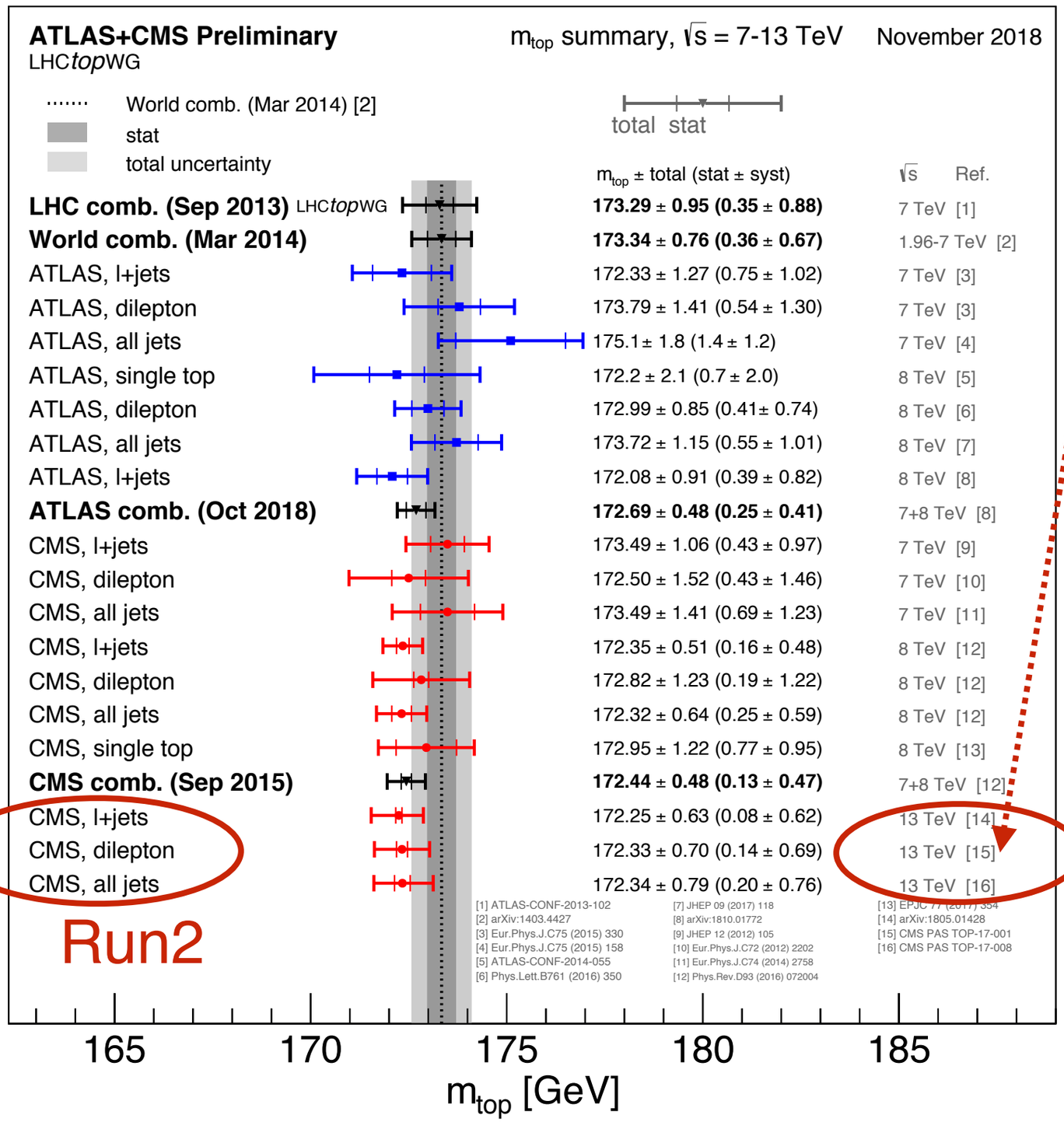
- full Run-2: work on reducing systematics

Run1+2: $m_H = 124.97 \pm 0.24$ (± 0.16 stat only) GeV

Top: the mass



- pole mass m_t from theory $\sigma(m_t^{pole}; PDF, \alpha_s; \mu_F, \mu_R, \ldots)$
- direct m_t reconstruction (match to MC)



Example CMS arXiv:1812.10505, fit:

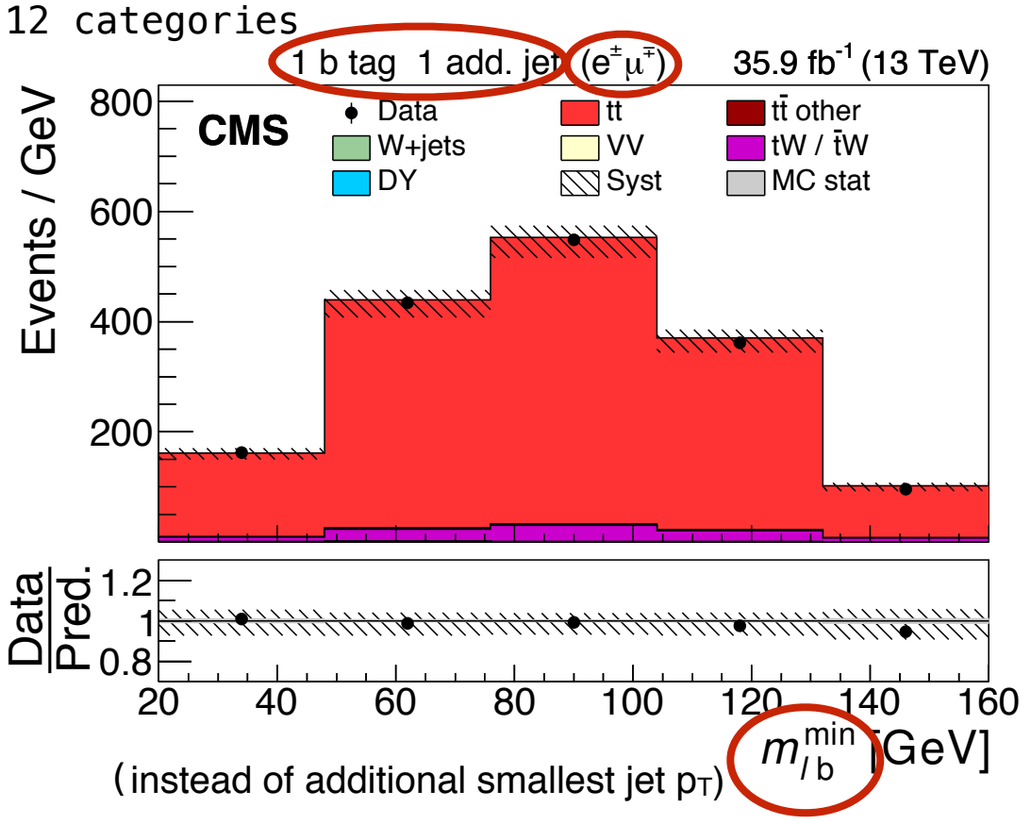
$$\sigma_{t\bar{t}} = 815 \pm 2\,(\text{stat}) \pm 29\,(\text{syst}) \pm 20\,(\text{lumi})\,\text{pb},$$

$$m_t^{MC} = 172.33 \pm 0.14\,(\text{stat})\,^{+0.66}_{-0.72}\,(\text{syst})\,\text{GeV}.$$

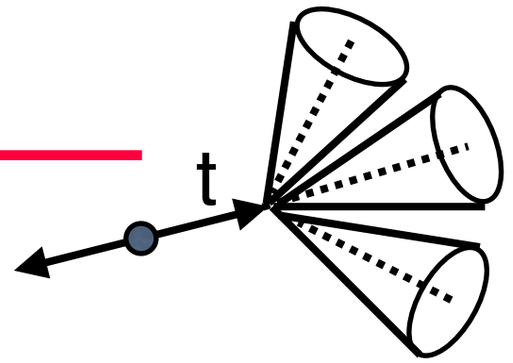
dominant JES (jet energy scale) uncert.

Extract m_t^{pole} [GeV] in pole mass scheme:

NNPDF3.1 $\quad 173.2 \pm 1.9\,(\text{fit} + \text{PDF} + \alpha_S)\,^{+0.9}_{-1.3}\,(\text{scale})$



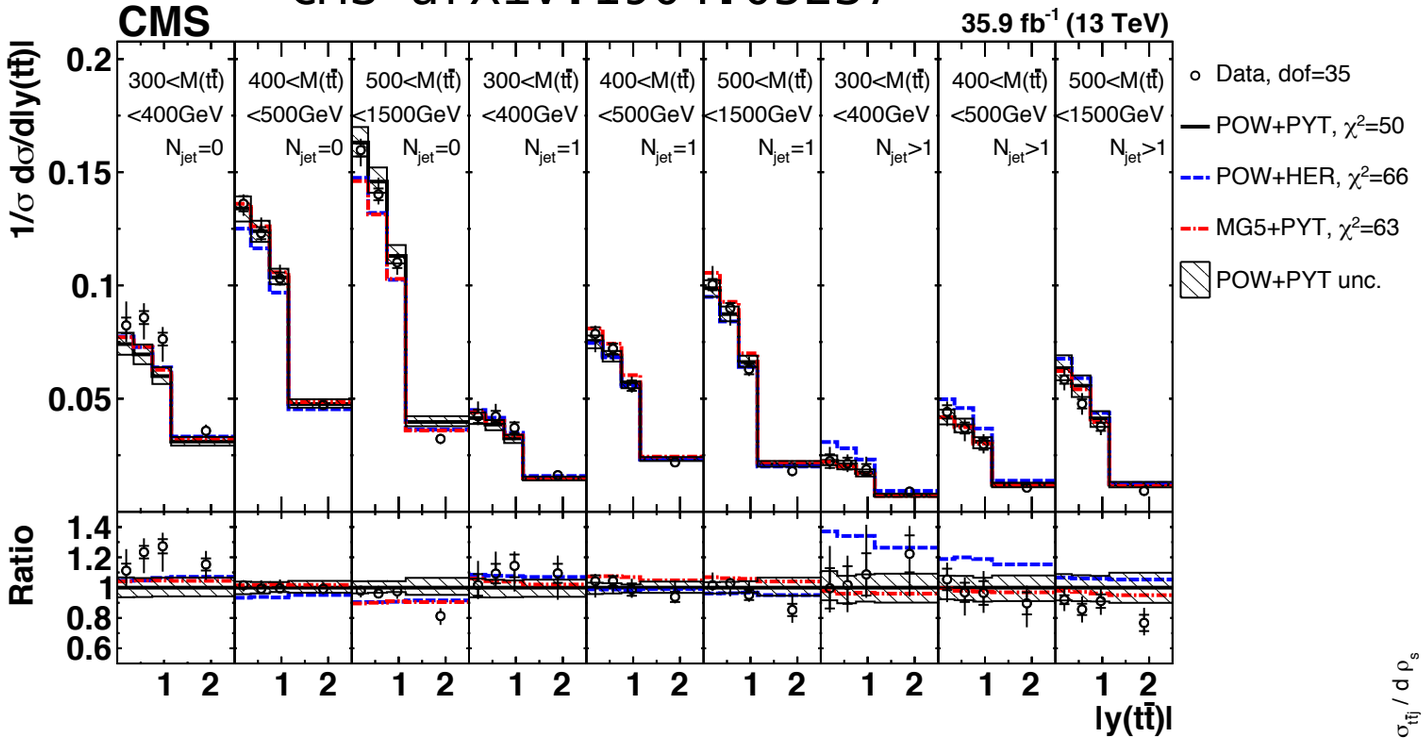
Top: the mass

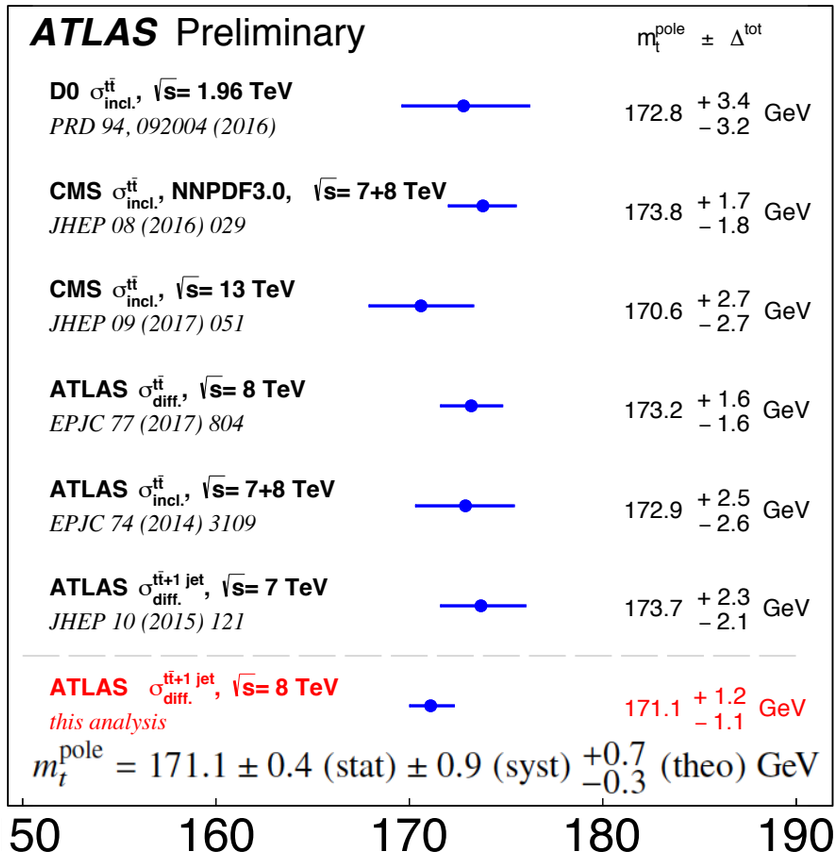


- pole mass m_t from theory $\sigma(m_t^{pole}; \text{PDF}, \alpha_s; \mu_F, \mu_R, \ldots)$
- triple-differential $[M(t\bar{t}), y(t\bar{t}), N_{jet}^{0,1,+}]$

$$e^{\pm}\mu^{\mp}, e^{+}e^{-}, \mu^{+}\mu^{-} \; + \geq 2 \text{ jets}$$

CMS arXiv:1904.05237

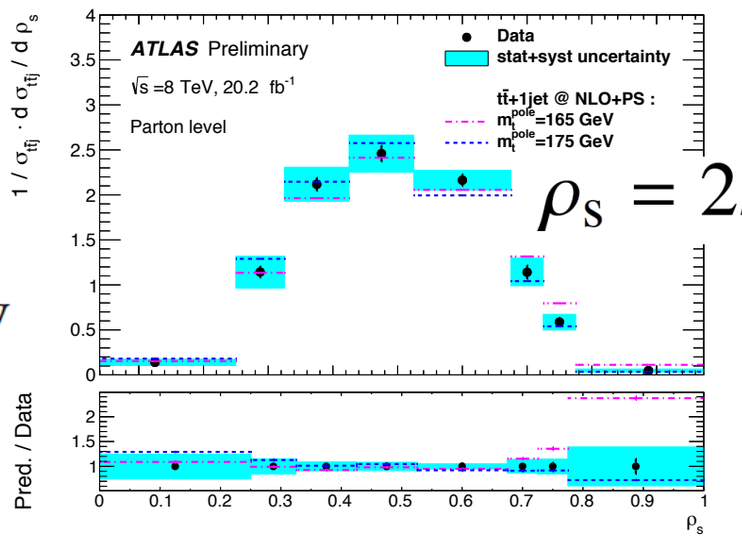




simultaneous fit $[m_t^{\text{pole}}, \alpha_S, \text{PDF}]$

$$m_t^{\text{pole}} = 170.5 \pm 0.7(\text{fit}) \pm 0.1(\text{model})^{+0.0}_{-0.1}(\text{param}) \pm 0.3(\text{scale}) \text{ GeV}$$

m_t^{pole} and m_t^{MC} differ, non-perturbative effects



$$\rho_s = 2m_0/m_{t\bar{t}+1\text{-jet}}$$

ℓ + jets

H, W/Z, top: the width / lifetime

- very short lived, yet relatively small width

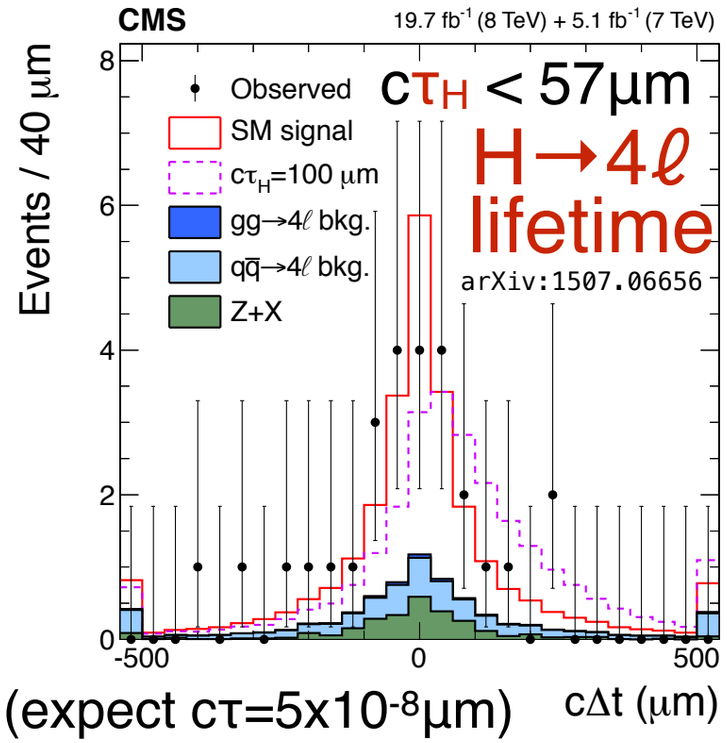
  $\tau_H = 1.6 \times 10^{-22}$ s $\Gamma_H \sim 0.004$ GeV

  $\tau_W = 3.2 \times 10^{-25}$ s $\Gamma_W \sim 2$ GeV

  $\tau_t = 5 \times 10^{-25}$ s $\Gamma_t \sim 1.3$ GeV

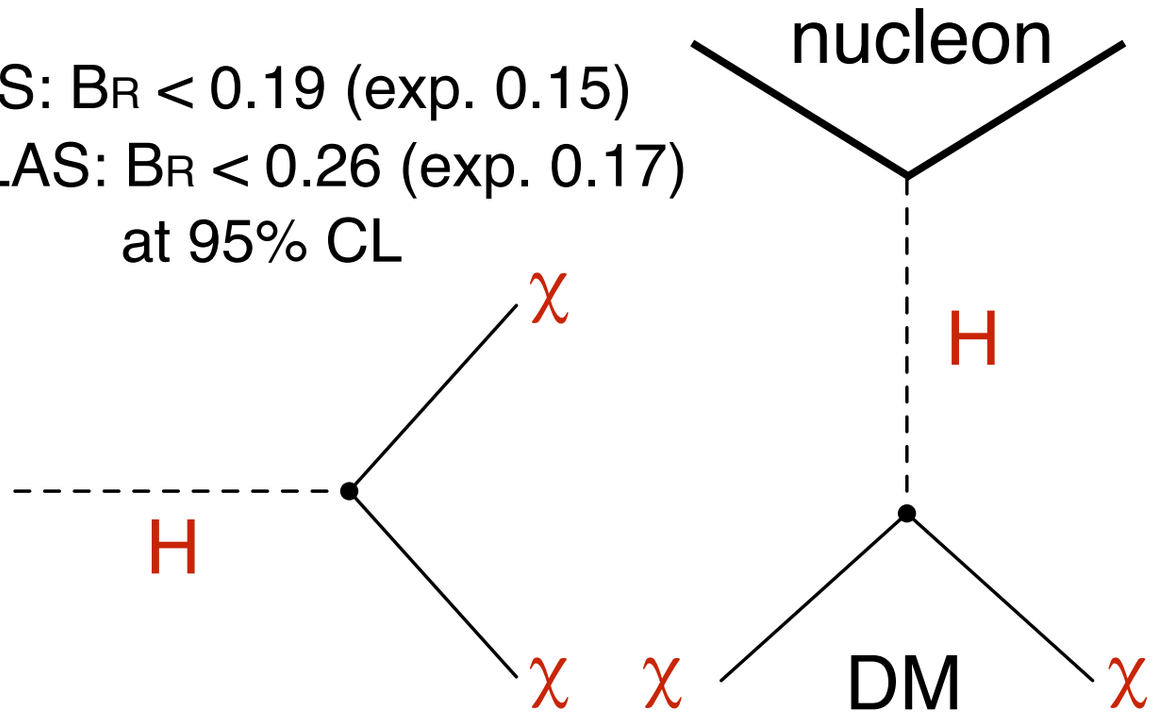
  (<< spin de-correlation)

- larger width may indicate BSM decay
  e.g. invisible or undetected

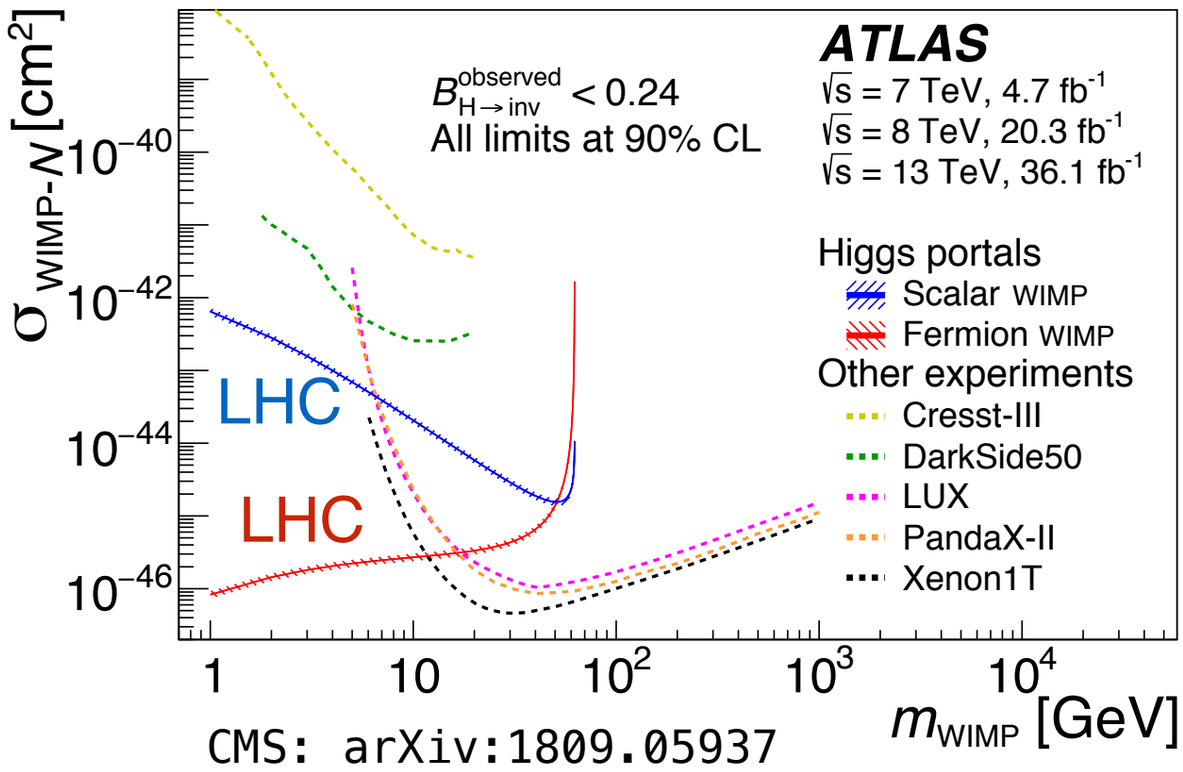


- also direct H→invisible

CMS: $B_R < 0.19$ (exp. 0.15)
ATLAS: $B_R < 0.26$ (exp. 0.17)
at 95% CL



ATLAS: arXiv:1904.05105

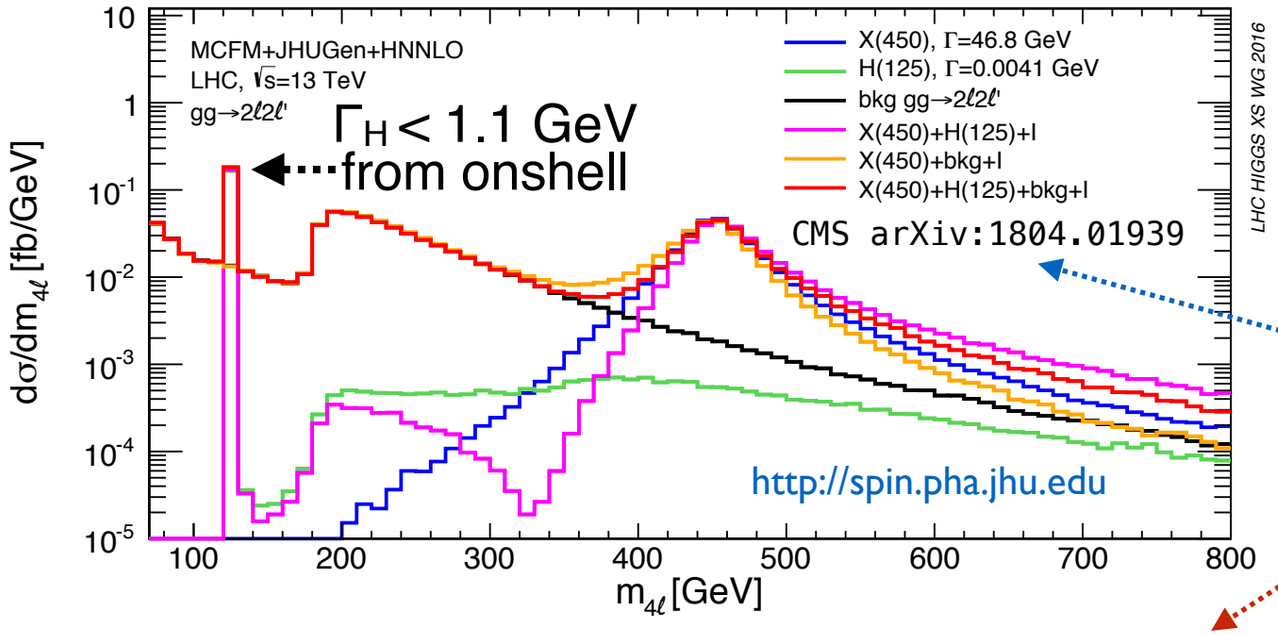


CMS: arXiv:1809.05937

H: the width (offshell H*)

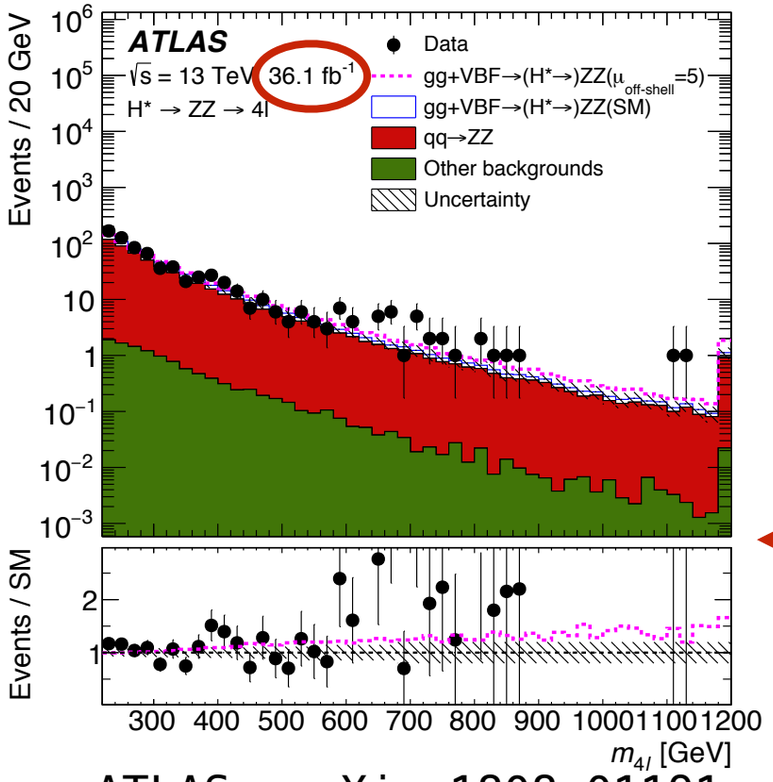
H→ZZ* (onshell) vs. H*→ZZ (offshell)

$$\frac{\mathrm{d}\,\sigma_{gg\to H\to ZZ}}{\mathrm{d}\,m^2_{ZZ}} \sim \frac{g^2_{\mathrm{ggH}} g^2_{\mathrm{HZZ}}}{(m^2_{ZZ}-m^2_H)^2 + m^2_H \Gamma_H{}^2}$$



~ 10% in SM, but:
offshell "enhancement"

(1) larger width Γ_H
(2) new resonance X
(3) anomalous couplings



ATLAS: arXiv:1808.01191

CMS (H→4ℓ)

$\Gamma_H = 3.2^{+2.8}_{-2.2}$ MeV

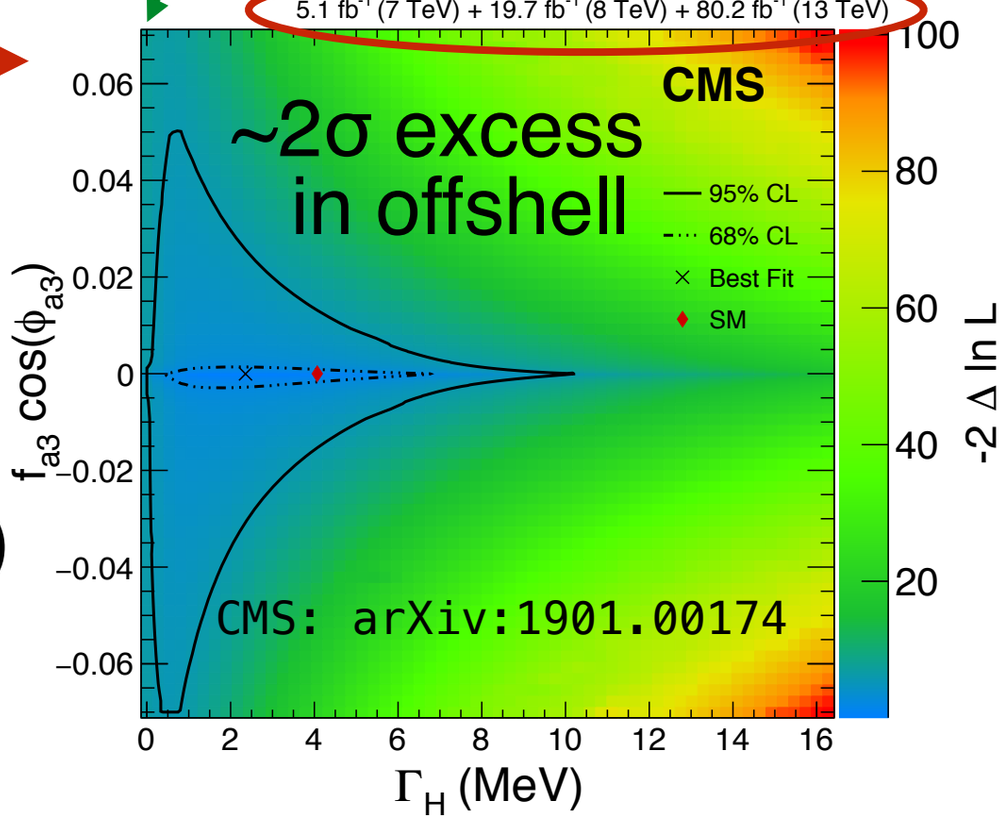
$0.08 < \Gamma_H < 9.16$ MeV

(exp. <13.7 MeV)

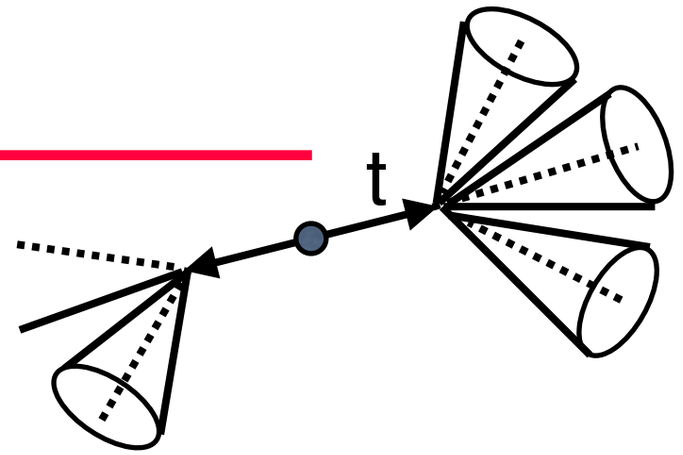
ATLAS (4ℓ+2ℓ2ν)

$\Gamma_H < 14.4$ MeV

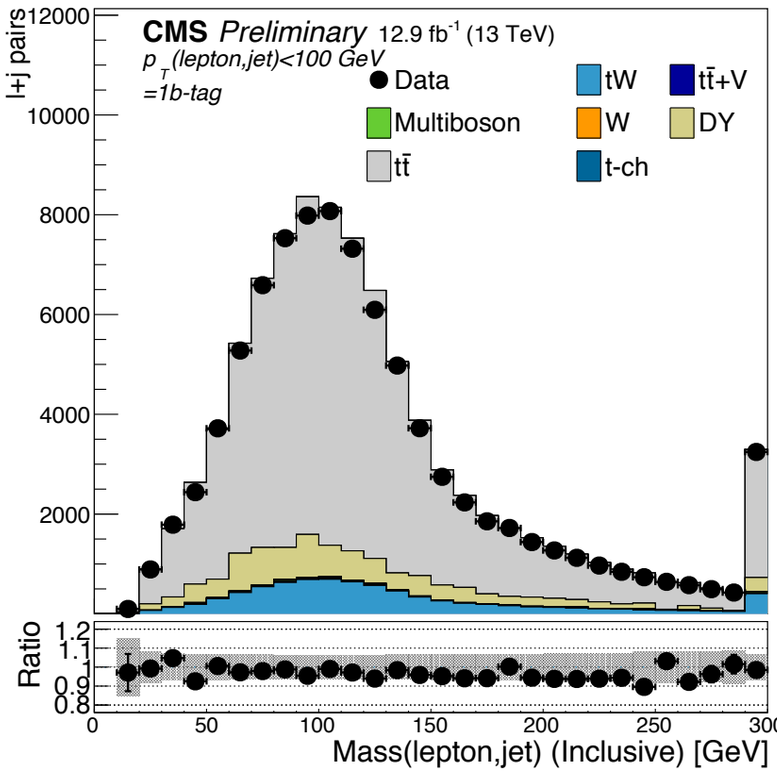
(exp. <15.2 MeV)



Top: the width

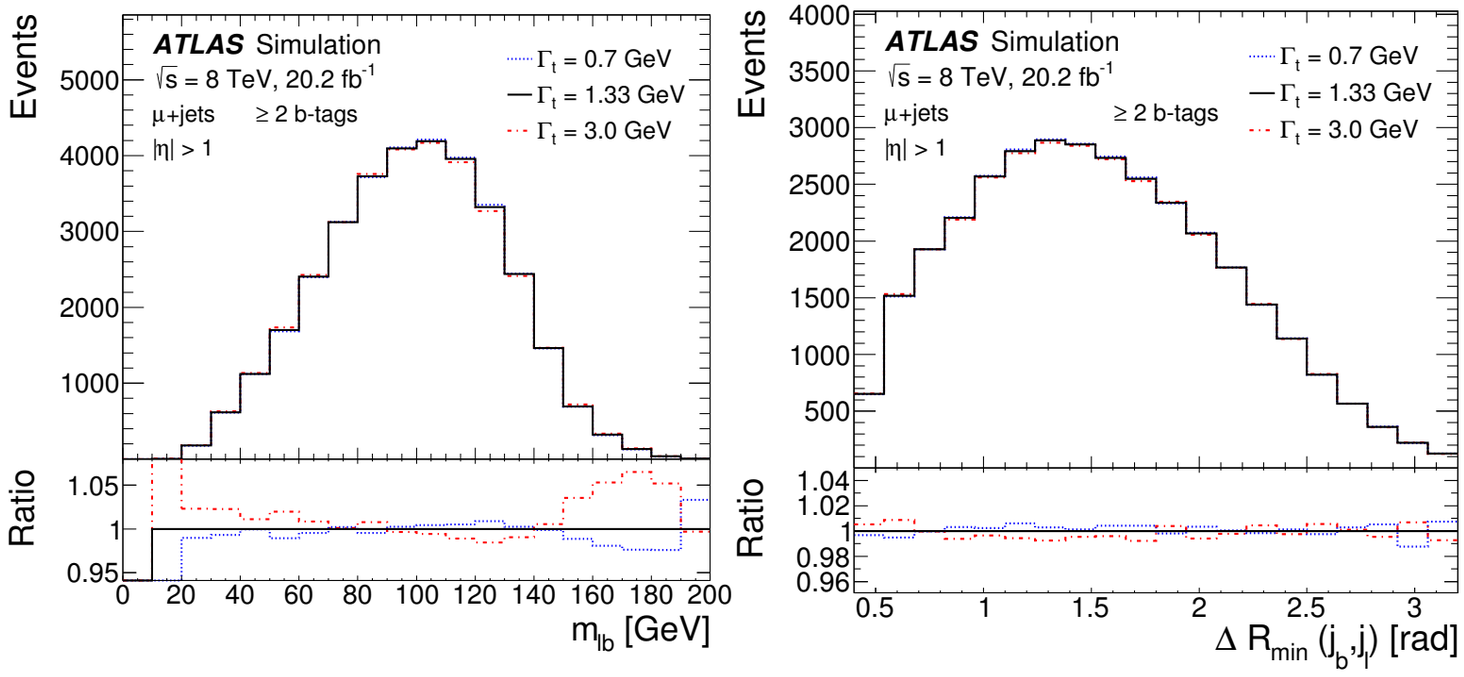


- expected Γ_t ~1.32 GeV (~ ±0.08 GeV)
  modified by V_{tb}, FCNC…
- indirect constraints (PDG): from BR(t→Wb/Wq), σ(single-top)
  ~ ±0.14 GeV, but scaling SM calculations
- direct: CMS-PAS-TOP-16-019



$0.6 \leq \Gamma_t \leq 2.5$ GeV

ATLAS arXiv:1709.04207



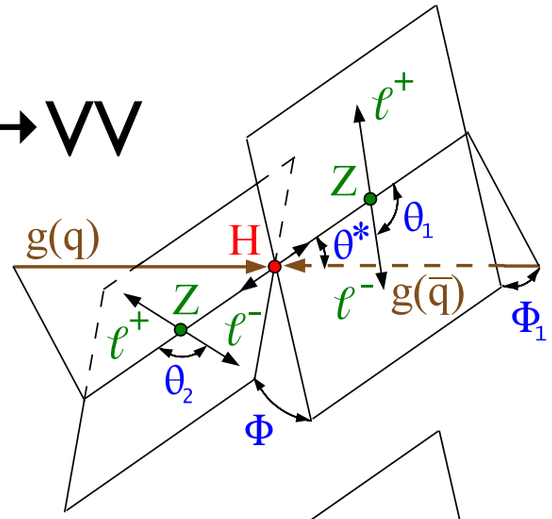
template fit 8 categories

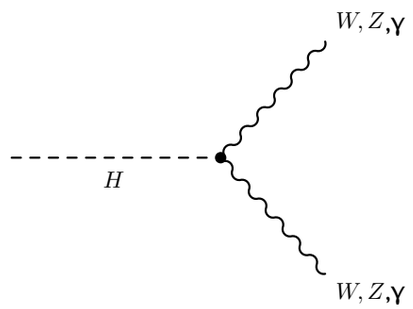
$\Gamma_t = 1.76 \pm 0.33\ (\text{stat.})\ ^{+0.79}_{-0.68}\ (\text{syst.})$

H,W/Z, top: spin correlations

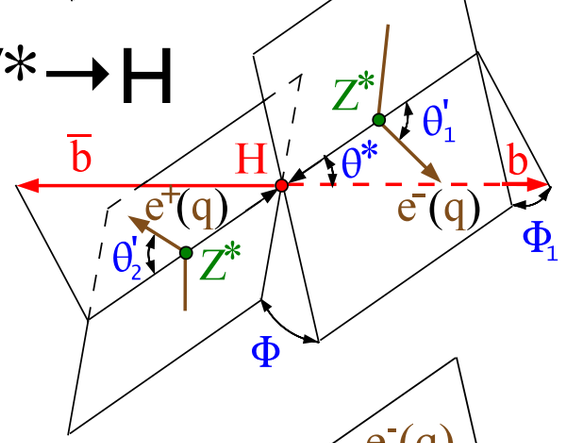
- Access to spin, parity, anomalous couplings in kinematics

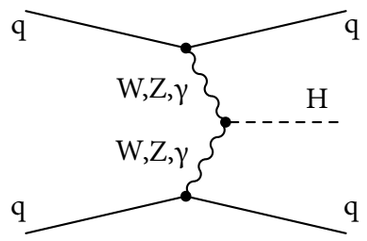
H→VV



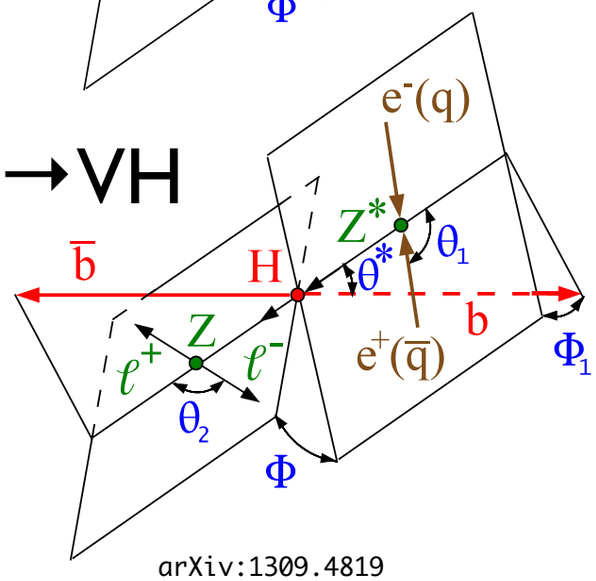


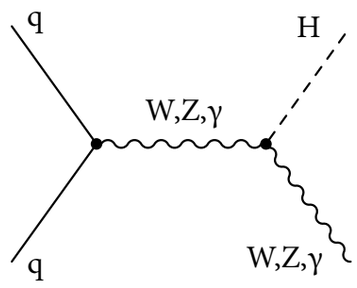
V*V*→H



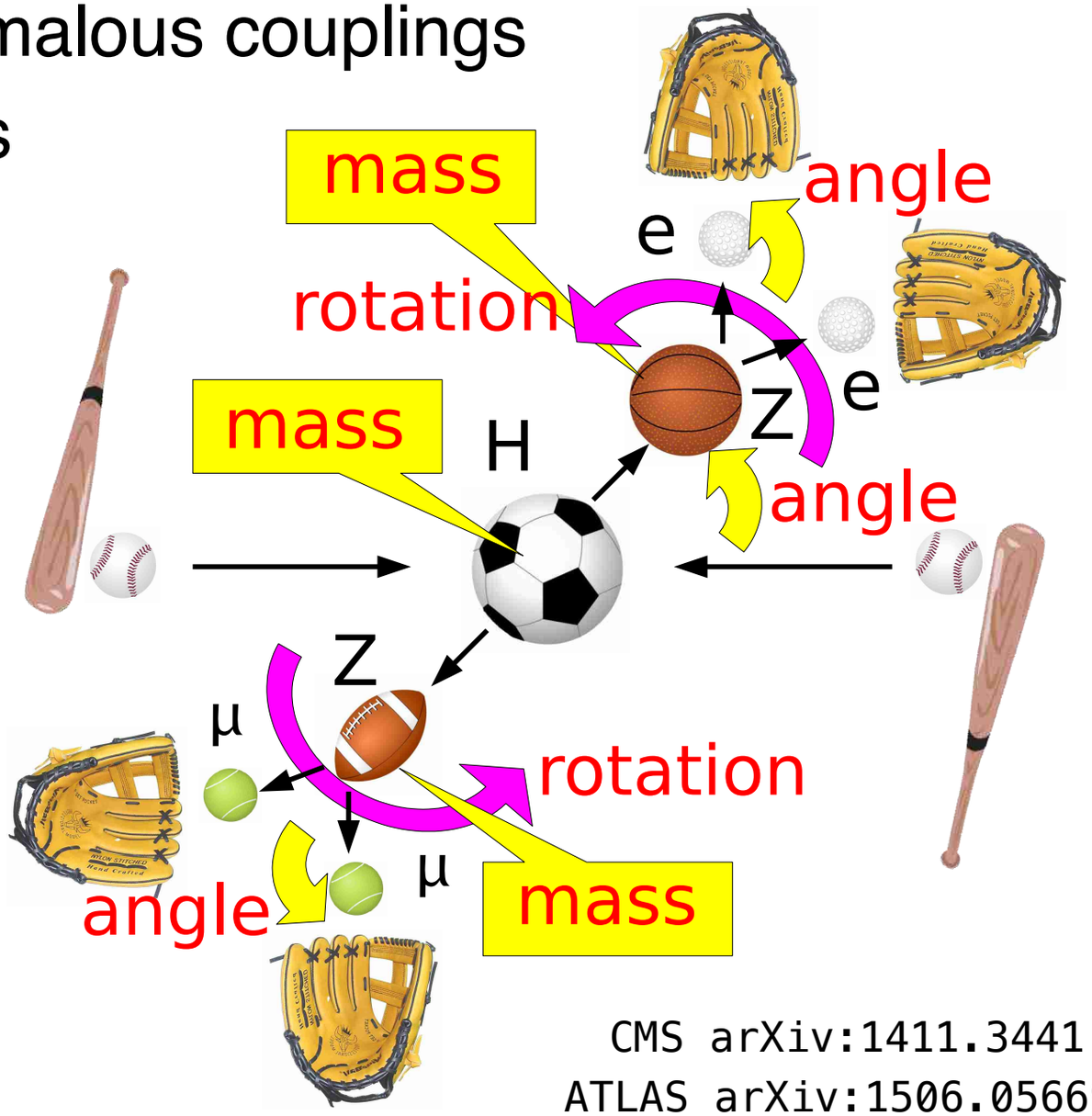


V*→VH





arXiv:1309.4819

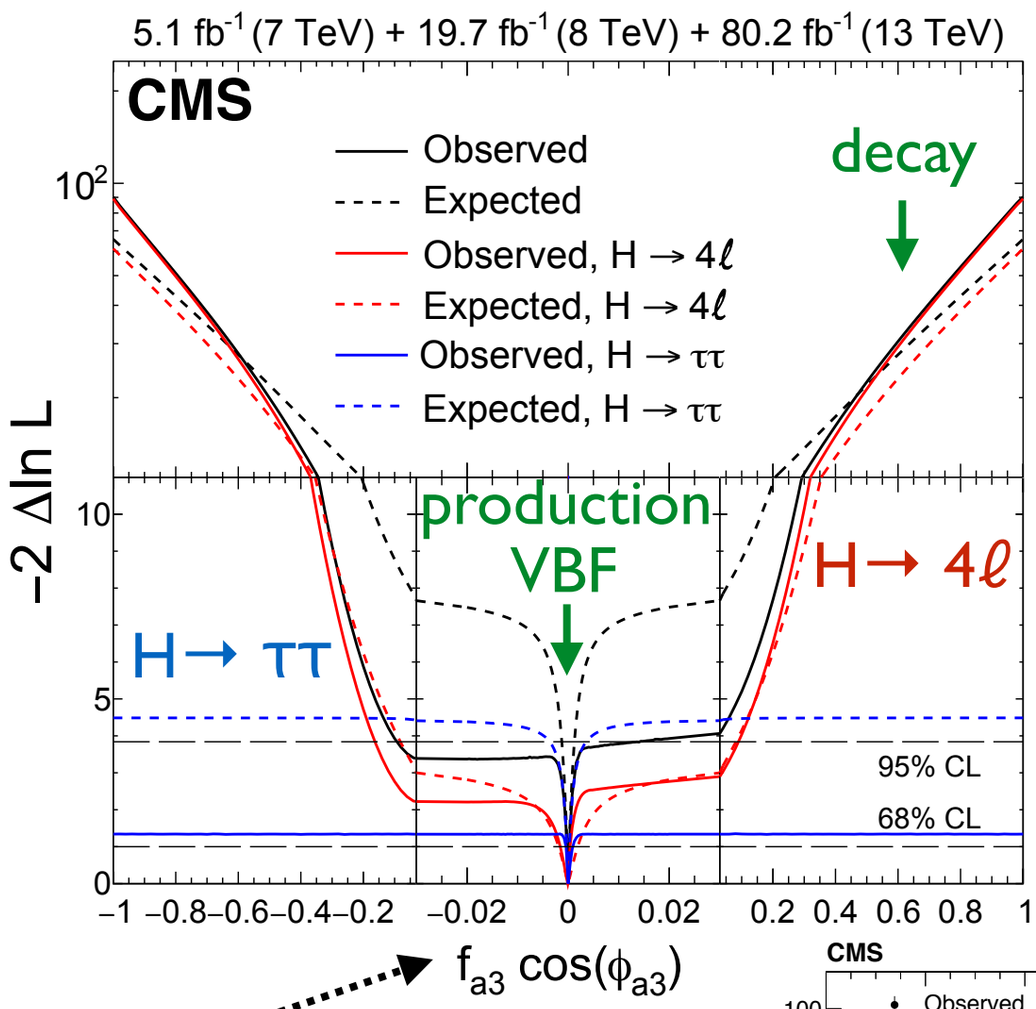


CMS arXiv:1411.3441
ATLAS arXiv:1506.05669

- Run-1 legacy: if H has certain J^{PC} then $J^{PC}=0^{++}$ (vacuum quantum numbers) possible small anomalous scalar couplings

H: spin correlations

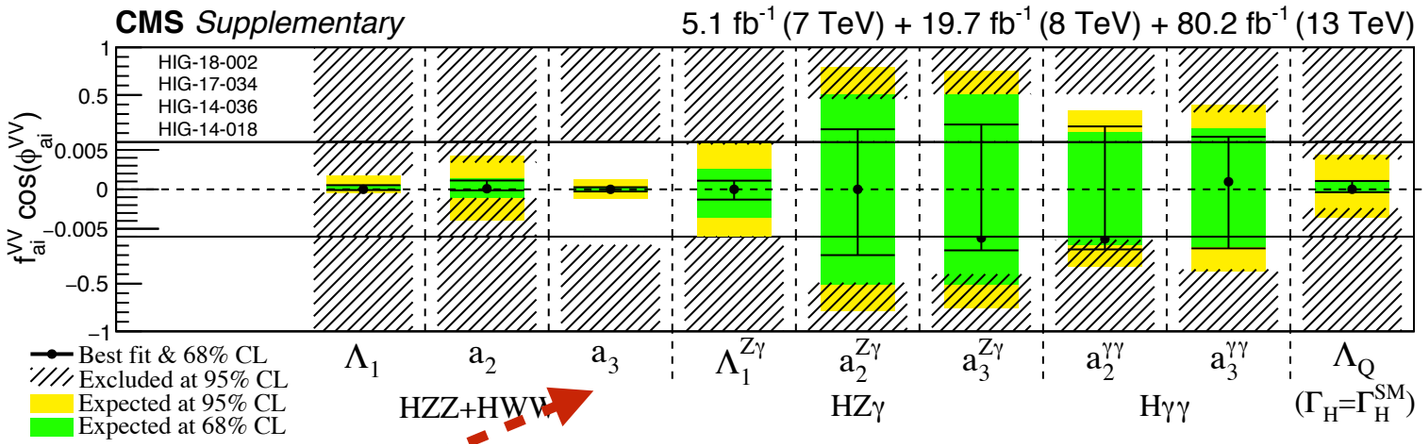
- CMS arXiv:1903.06973

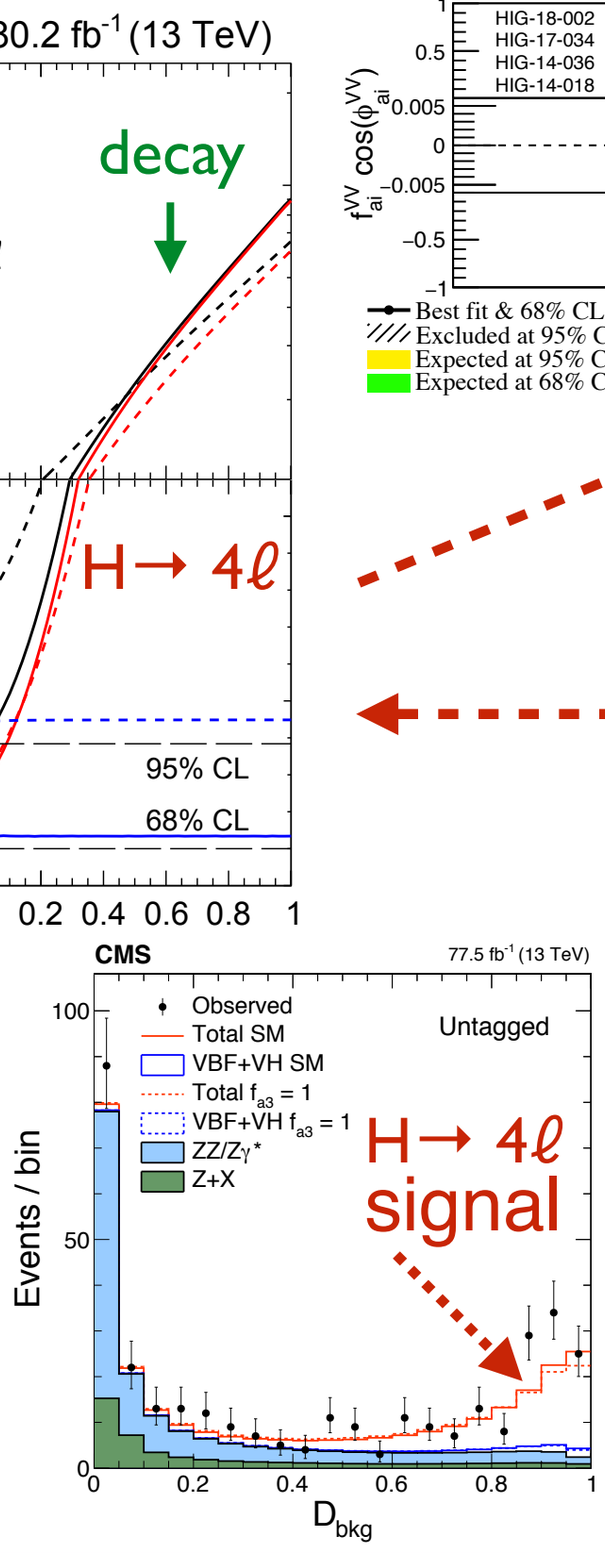


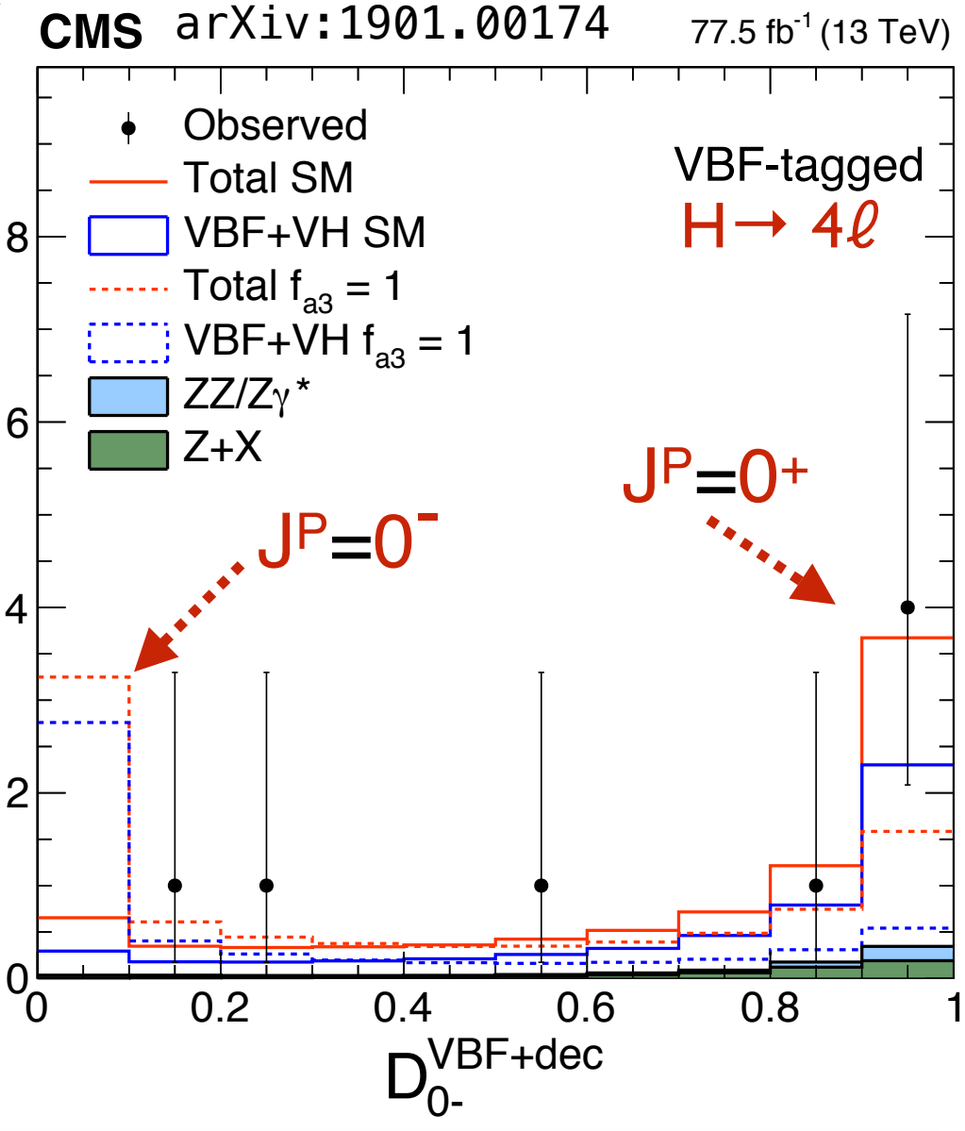
fraction of anomalous effects (e.g. CP-violation)

CP-odd: $f_{a3} < 0.092$

CP-even: $f_{a2} < 0.0034$

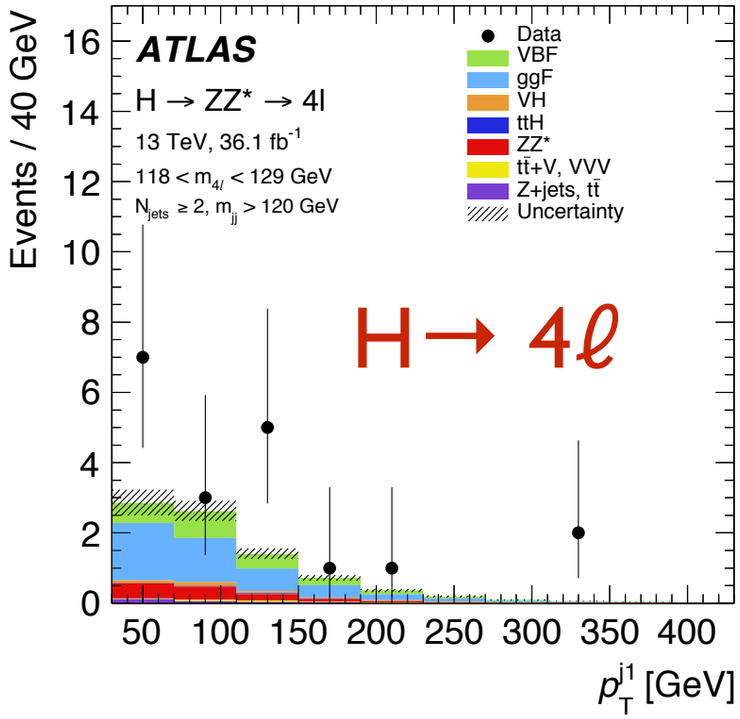






H: spin correlations

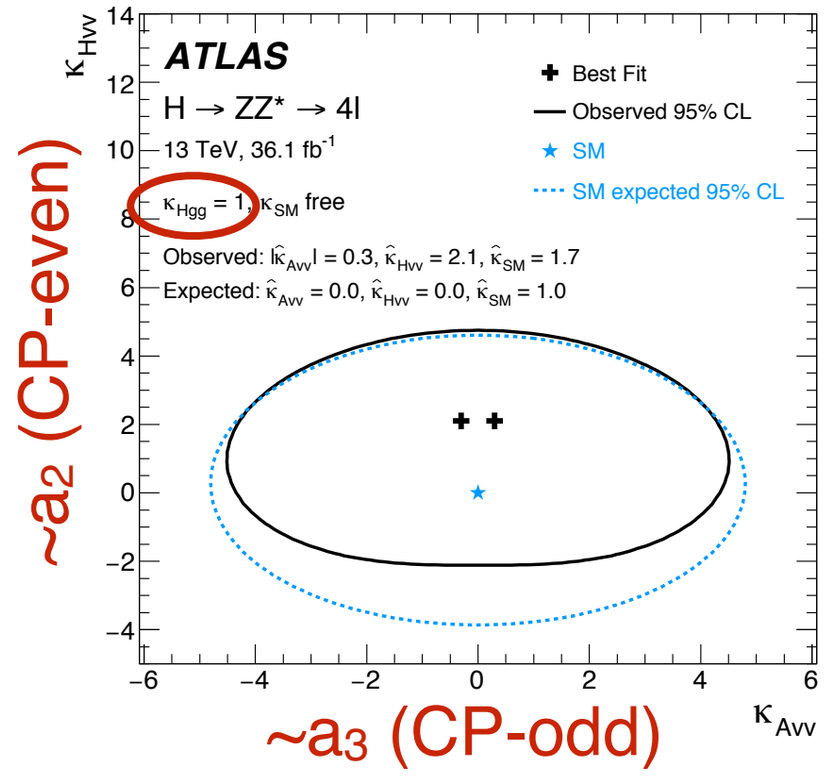
- ATLAS arXiv:1712.02304



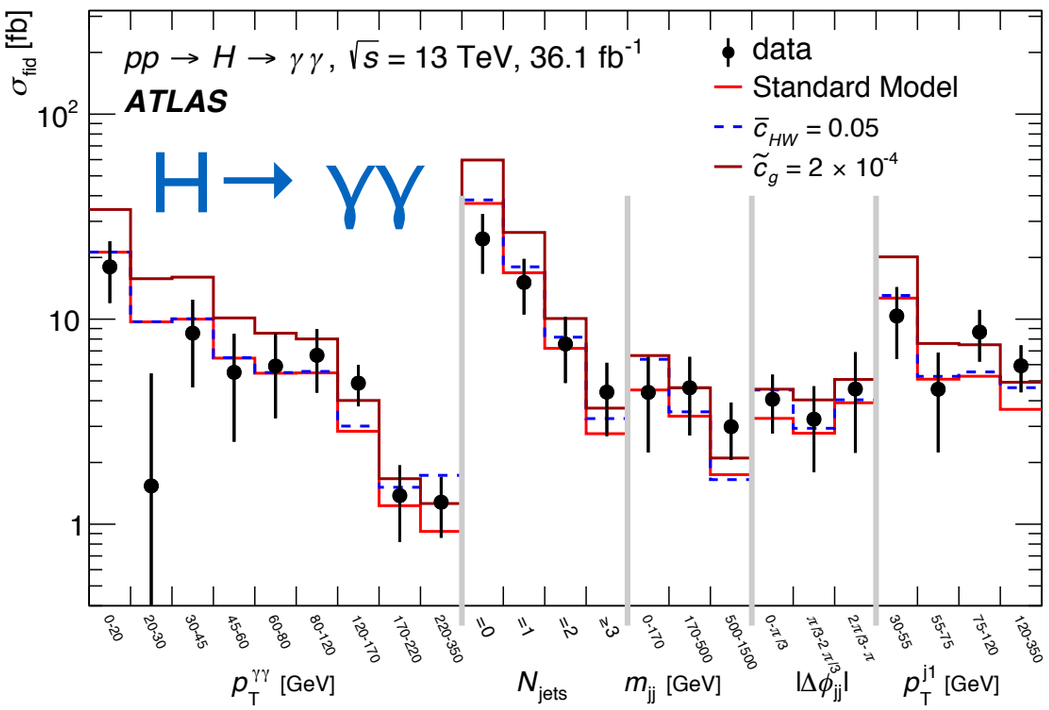
10 categories

partial STXS stage1.0 (more later)

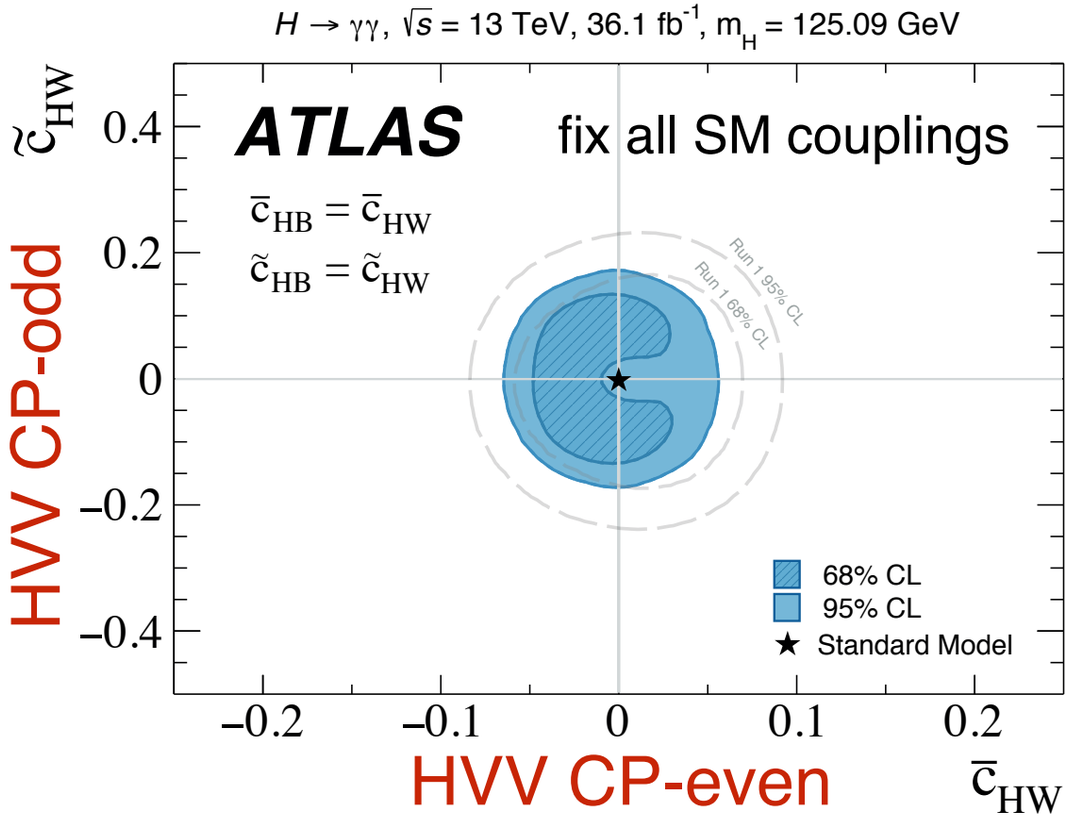
mostly p_T(H or jet)



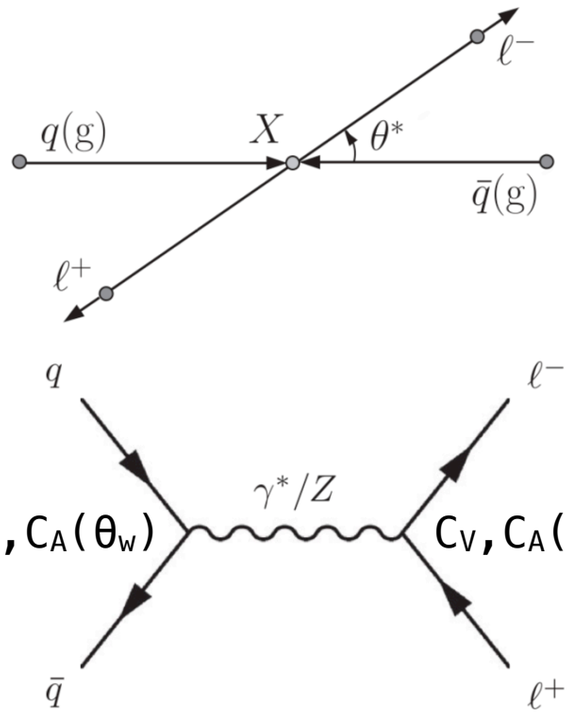
- ATLAS arXiv:1802.04146 5 differential XS

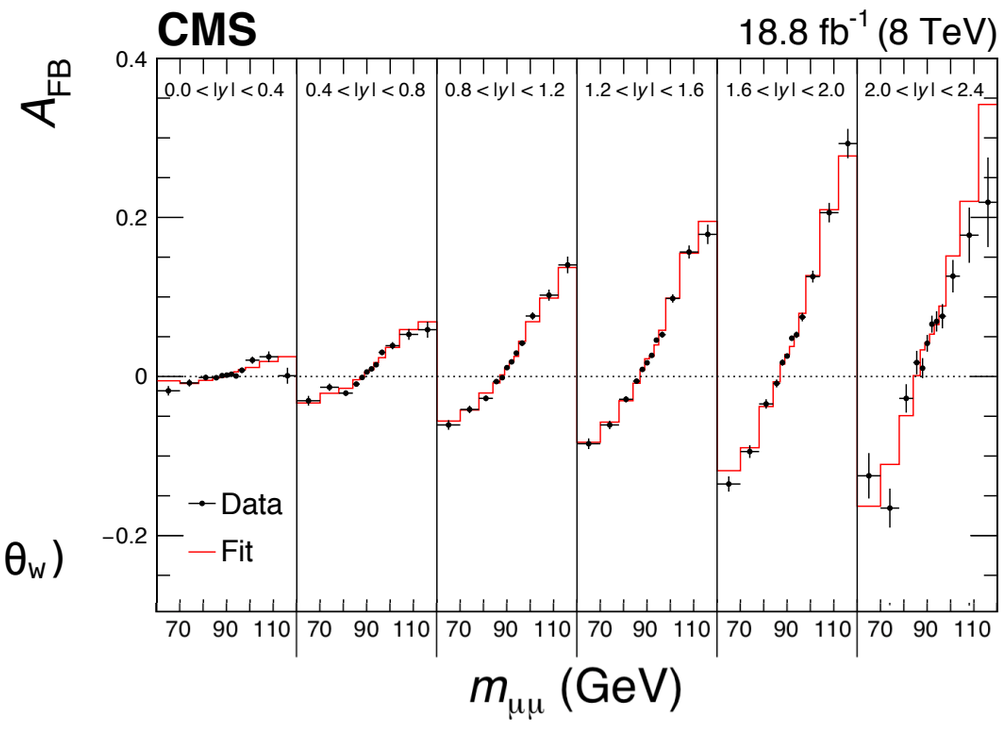


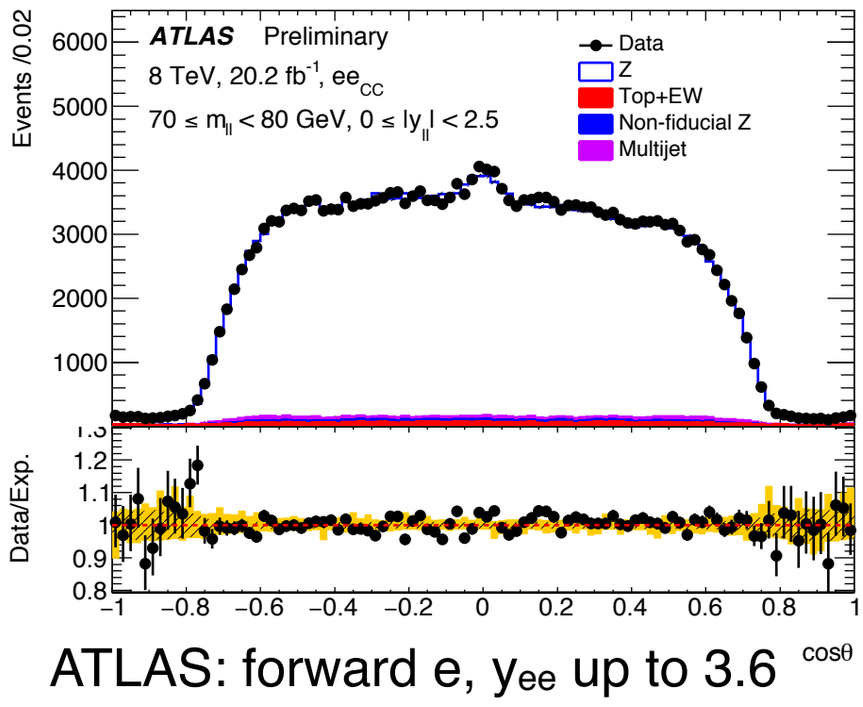
"bootstrapping" for correlations



Z/γ*: spin correlations (weak mixing angle θ_W)



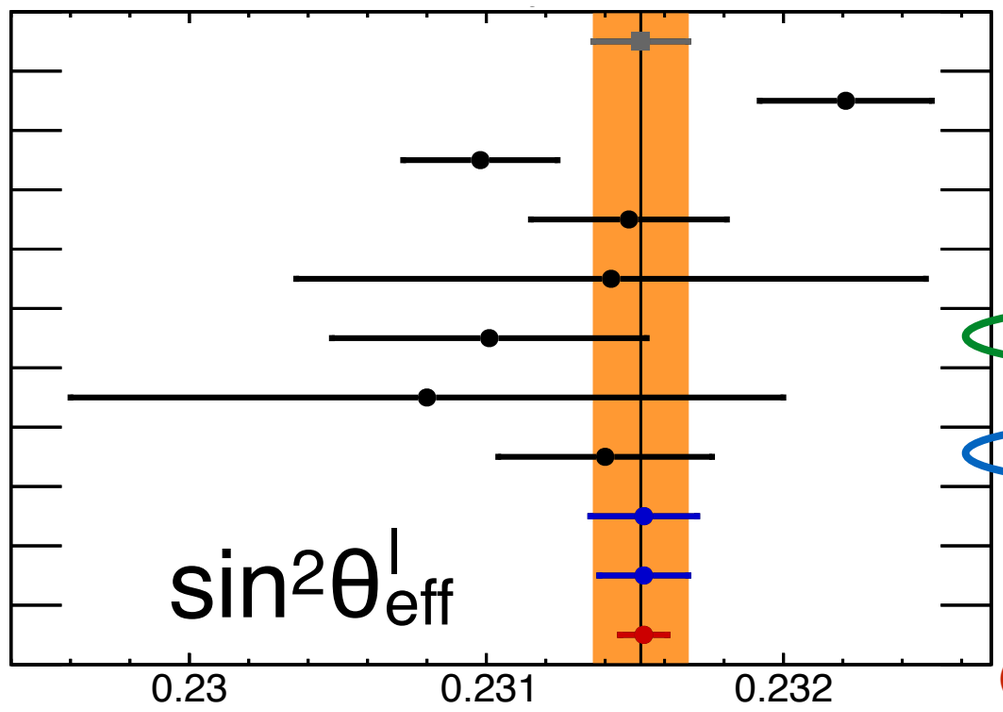




ATLAS: forward e, y_{ee} up to 3.6

CMS: 0.23101 ± 0.00036 (stat.) ± 0.00031 (PDF) ± 0.00018 (syst.) ± 0.00016 (theo.)

ATLAS: 0.23140 ± 0.00021 (stat.) ± 0.00024 (PDF) ± 0.00016 (syst.)



LEP-1 and SLD: Z-pole average	0.23152 ± 0.00016
LEP-1 and SLD: $A_{FB}^{0,b}$	0.23221 ± 0.00029
SLD: A_l	0.23098 ± 0.00026
Tevatron	0.23148 ± 0.00033
LHCb: 7+8 TeV	0.23142 ± 0.00106
CMS: 8 TeV	0.23101 ± 0.00053
ATLAS: 7 TeV	0.23080 ± 0.00120
ATLAS Preliminary: 8 TeV	0.23140 ± 0.00036
HL-LHC ATLAS CT14: 14 TeV	0.23153 ± 0.00018
HL-LHC ATLAS PDF4LHC15$_{HL-LHC}$: 14 TeV	0.23153 ± 0.00015
HL-LHC ATLAS PDFLHeC: 14 TeV	0.23153 ± 0.00008 (LHeC collider)

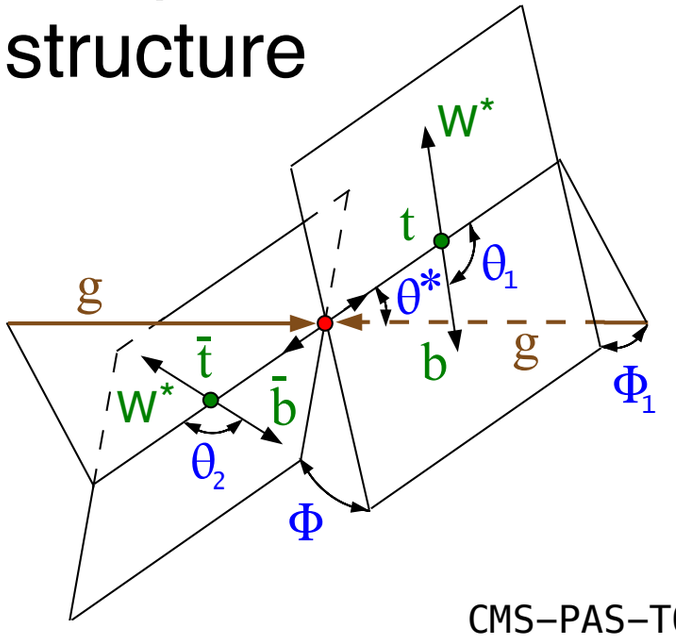
CMS: arXiv:1806.00863

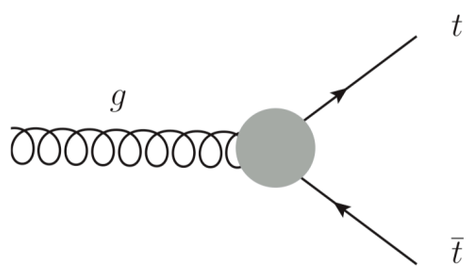
ATLAS-CONF-2018-037

expect HL-LHC 3000 fb^{-1}
ATL-PHYS-PUB-2018-037

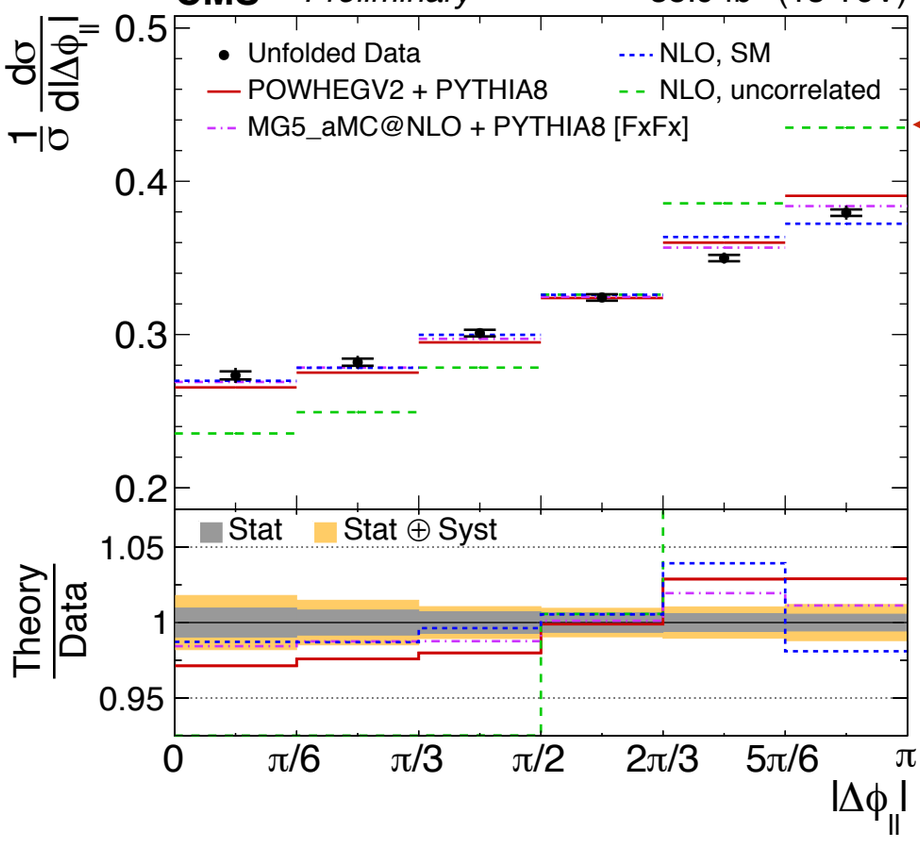
Top: spin correlations

- spin structure $|\mathcal{M}(q\bar{q}/gg \to t\bar{t} \to (\ell^+\nu b)(\ell^-\bar{\nu}\bar{b}))|^2 \sim Tr[\rho R \bar{\rho}]$





CMS-PAS-TOP-18-006



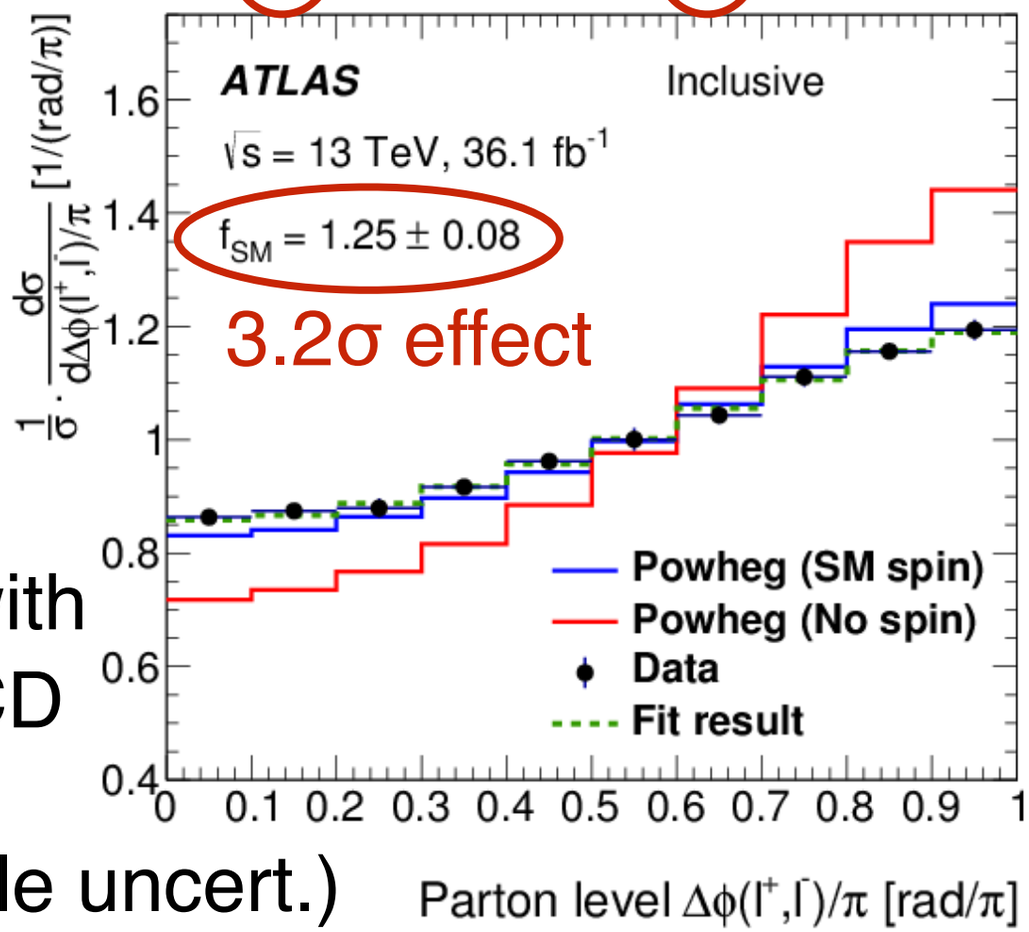
35k e^+e^-
70k $\mu^+\mu^-$
150k $e\mu$

- $\Delta\Phi_{\ell\ell}$ - analyzer
  enhance ~π (back-to-back) spin correlations
  enhance lower values

experimental unfolding

ATLAS: arXiv:1903.07570

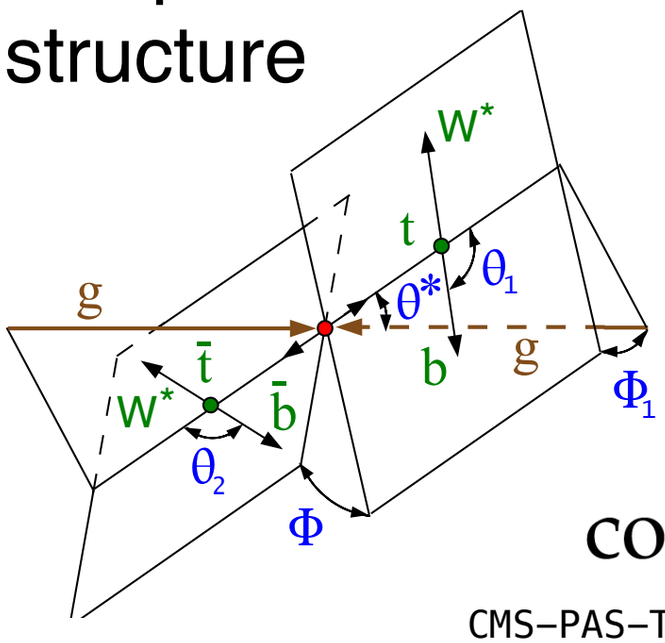
$x_i = f_{SM} \cdot x_{spin,\,i} + (1 - f_{SM}) \cdot x_{nospin,\,i}$

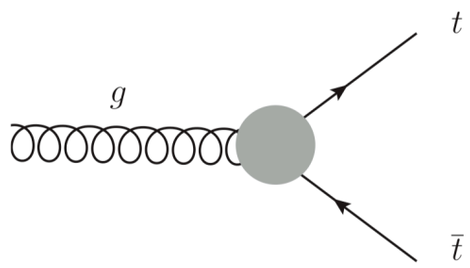


improve with
NNLO QCD
NLO EW
(large scale uncert.)

Top: spin correlations

- spin structure $|\mathcal{M}(q\bar{q}/gg \to t\bar{t} \to (\ell^+\nu b)(\ell^-\bar{\nu}\bar{b}))|^2 \sim Tr[\rho R \bar{\rho}]$



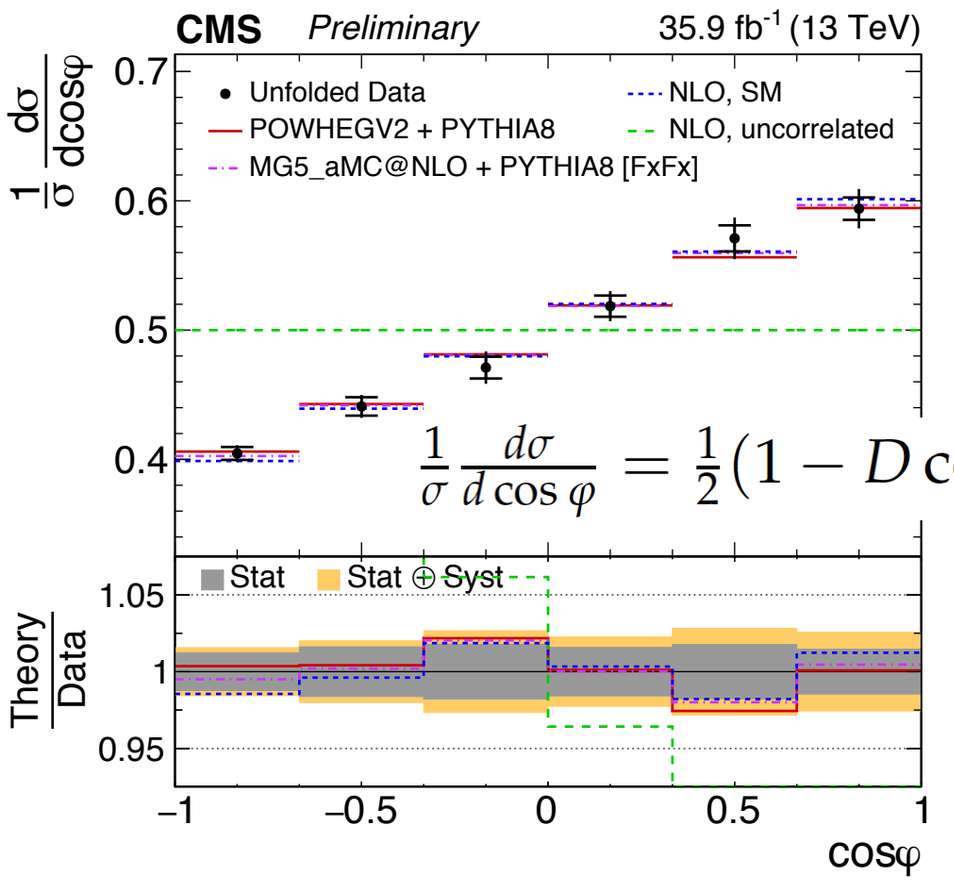


- CMS: 15+ coefficients describe R density matrix

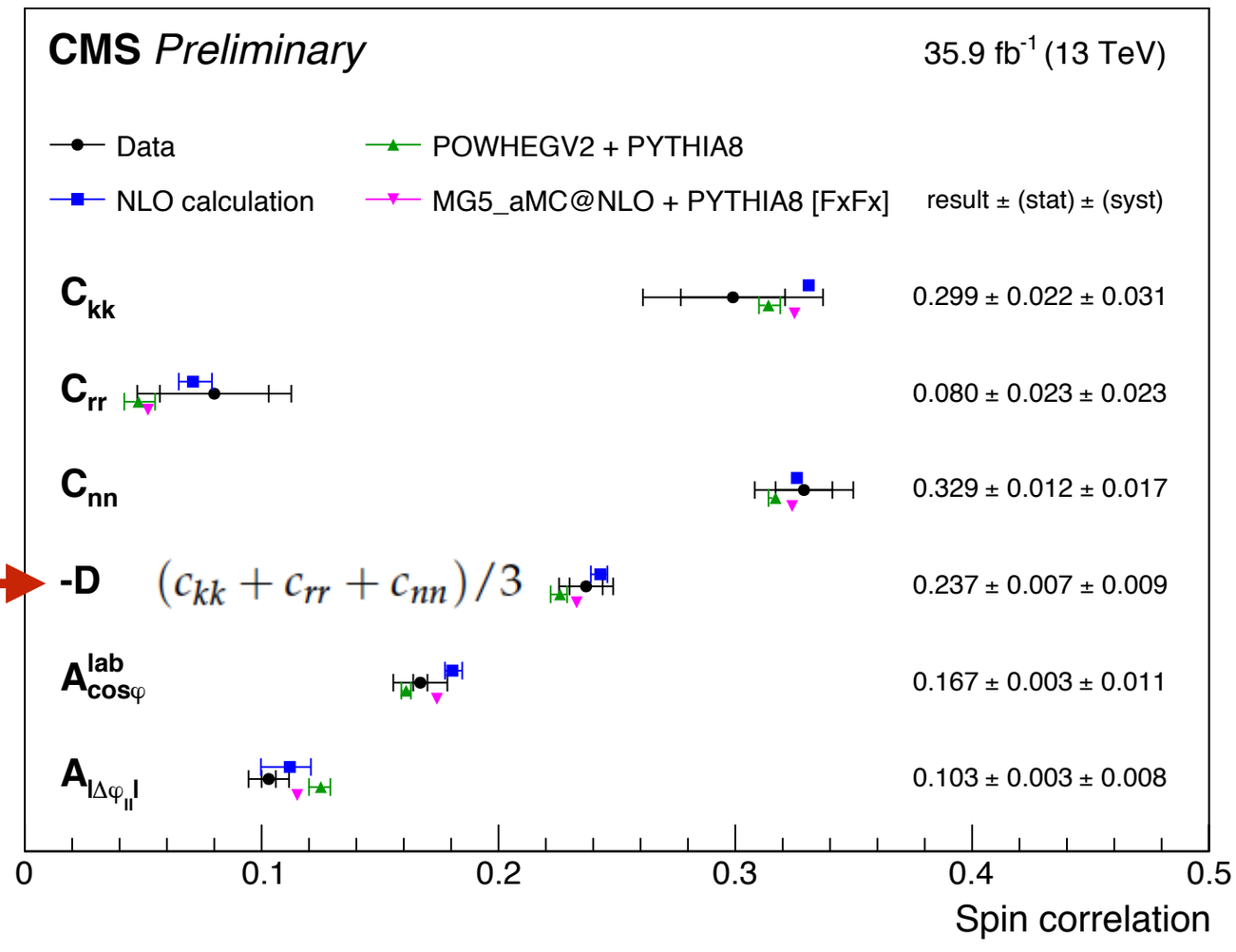
15+ differential distributions

$$\cos\varphi = \hat{\ell}_1 \cdot \hat{\ell}_2$$

CMS-PAS-TOP-18-006

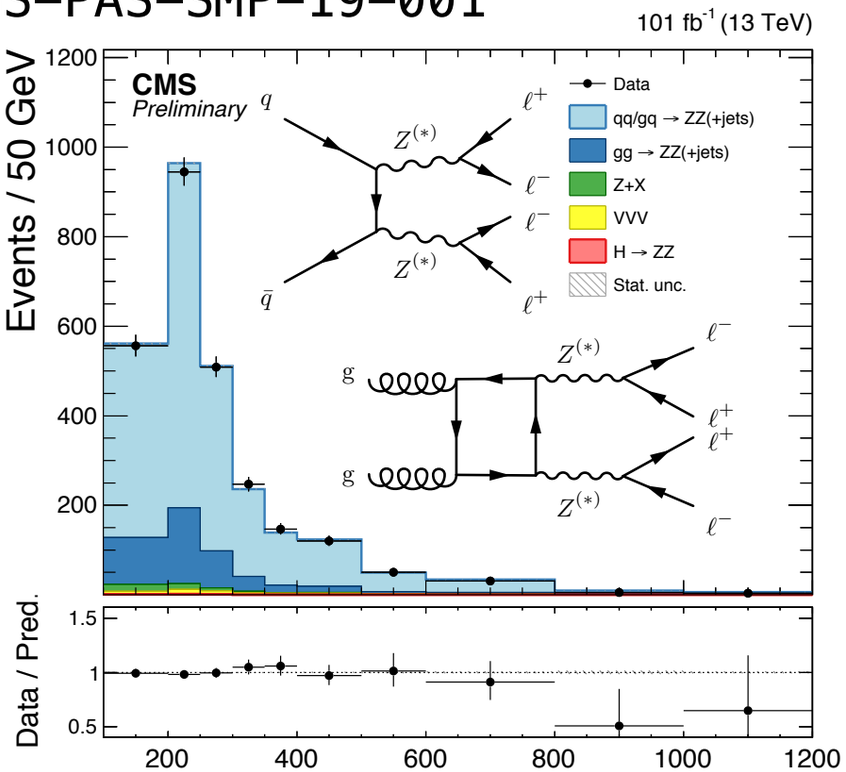


$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\varphi} = \frac{1}{2}(1 - D\cos\varphi)$$

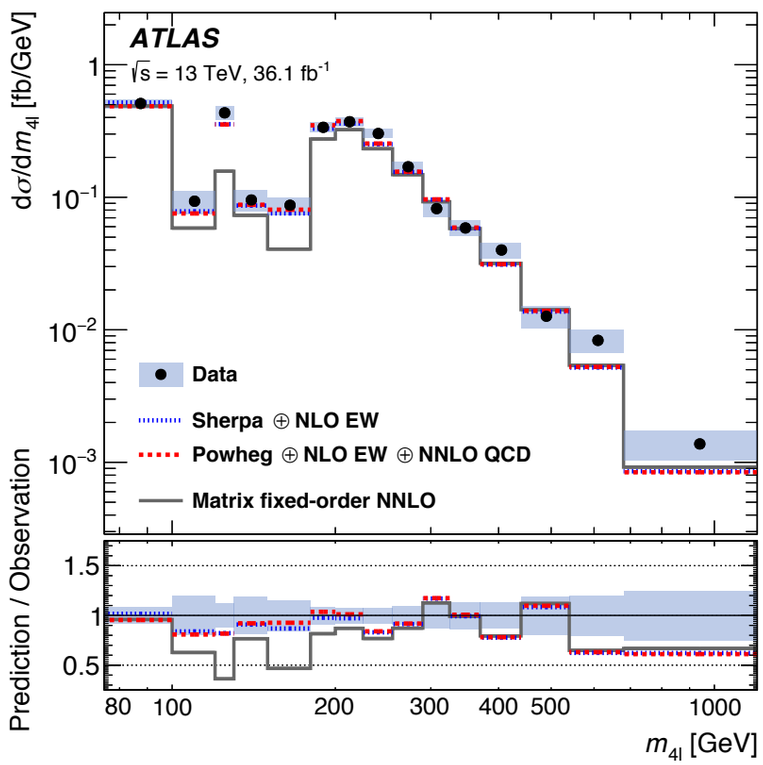


ZZ: couplings / cross sections (full Run2)

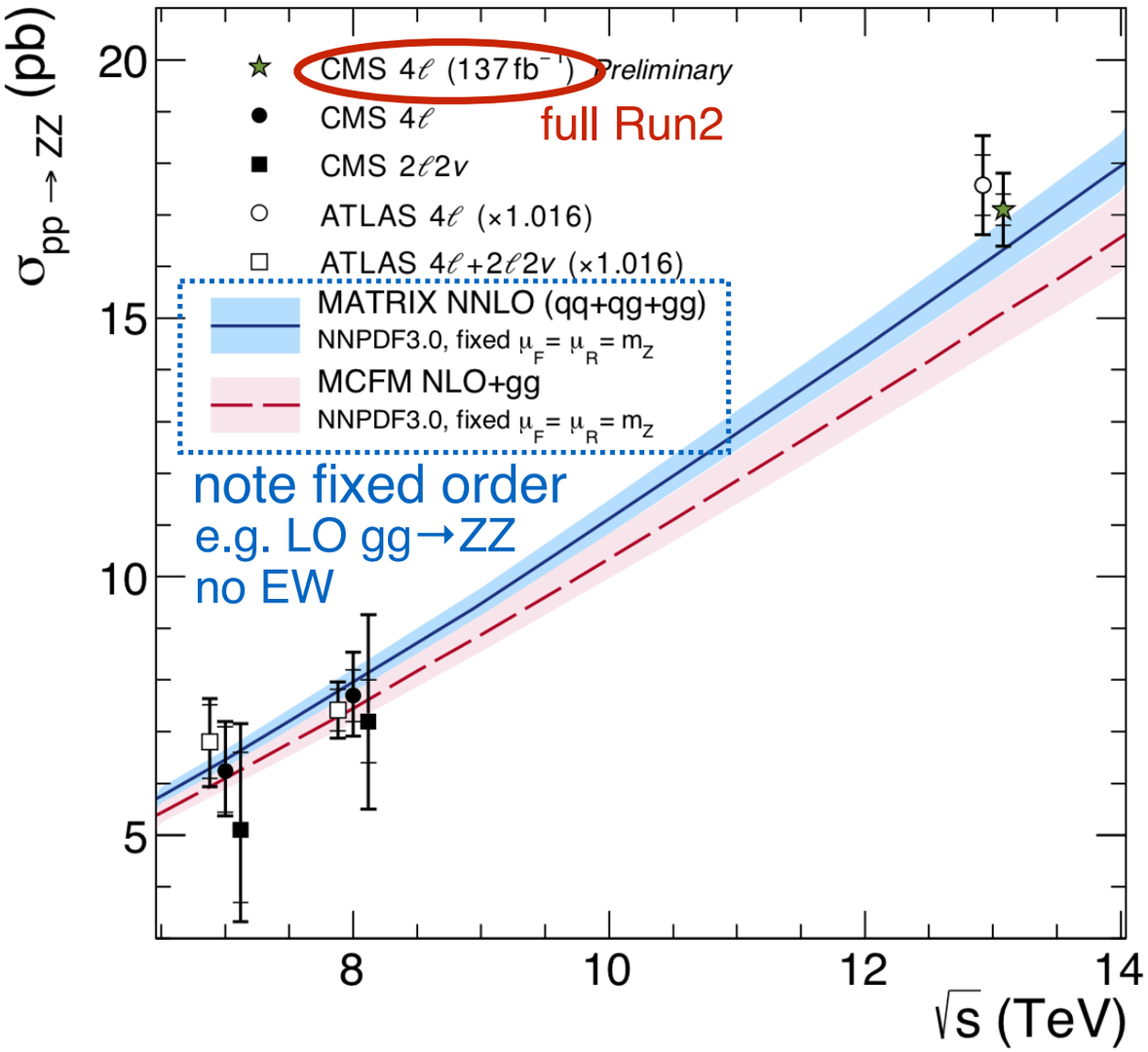
- CMS-PAS-SMP-19-001



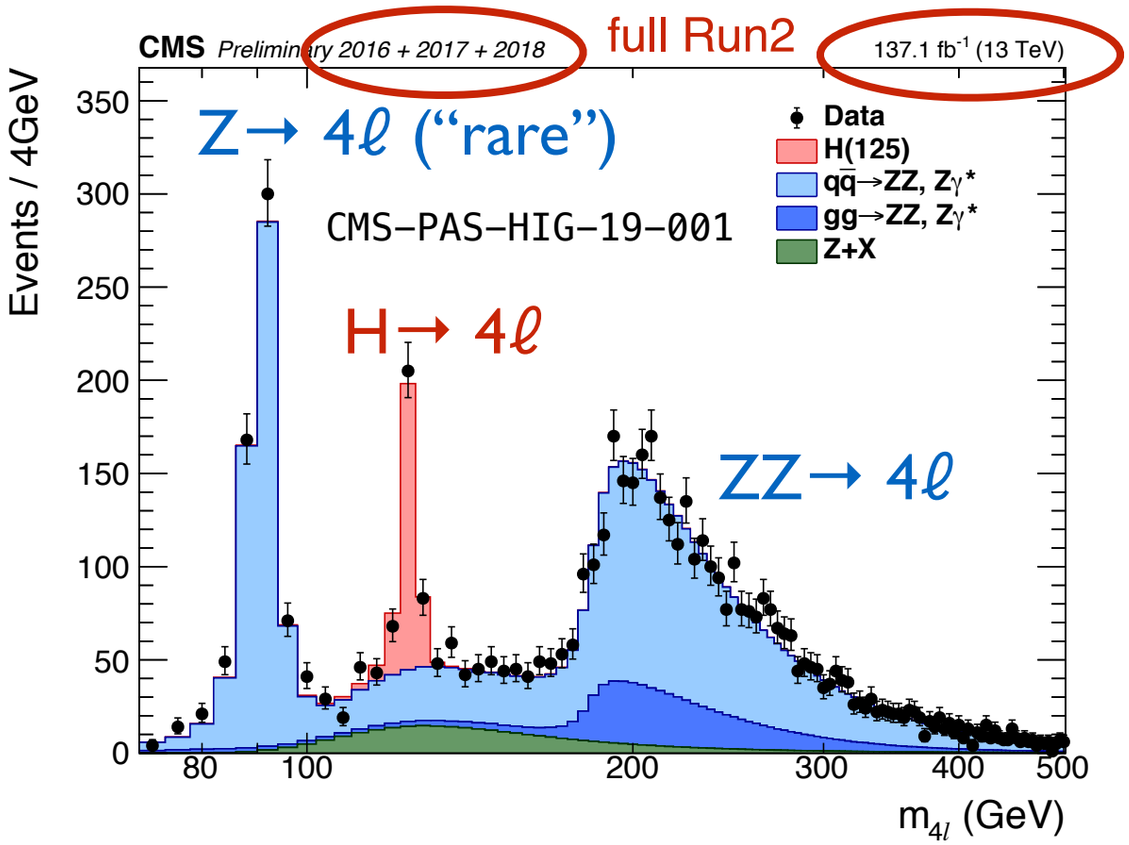
- ATLAS arXiv:1902.05892 m_{ZZ} [GeV]

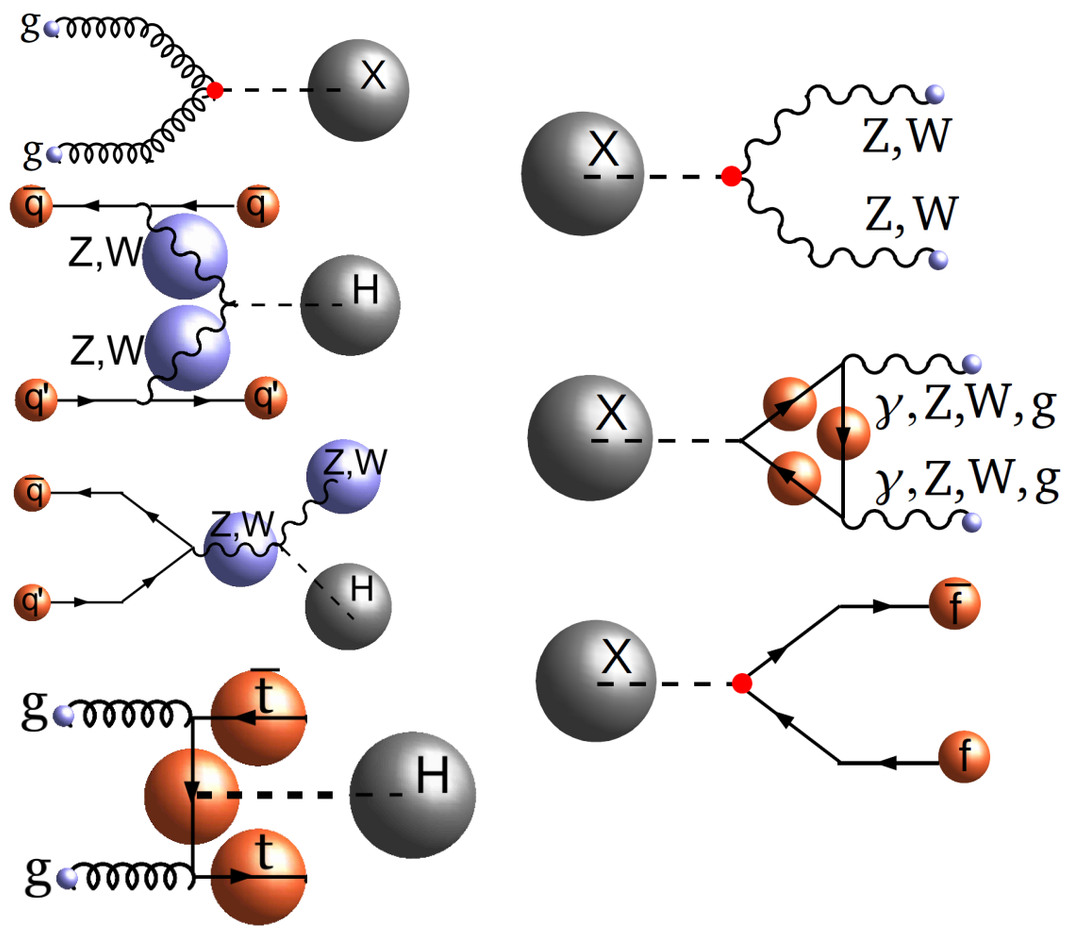


- Test higher order effects (QCD, EW)
  - —cross section and differential
- Important for H physics
  - —both on- and off-shell

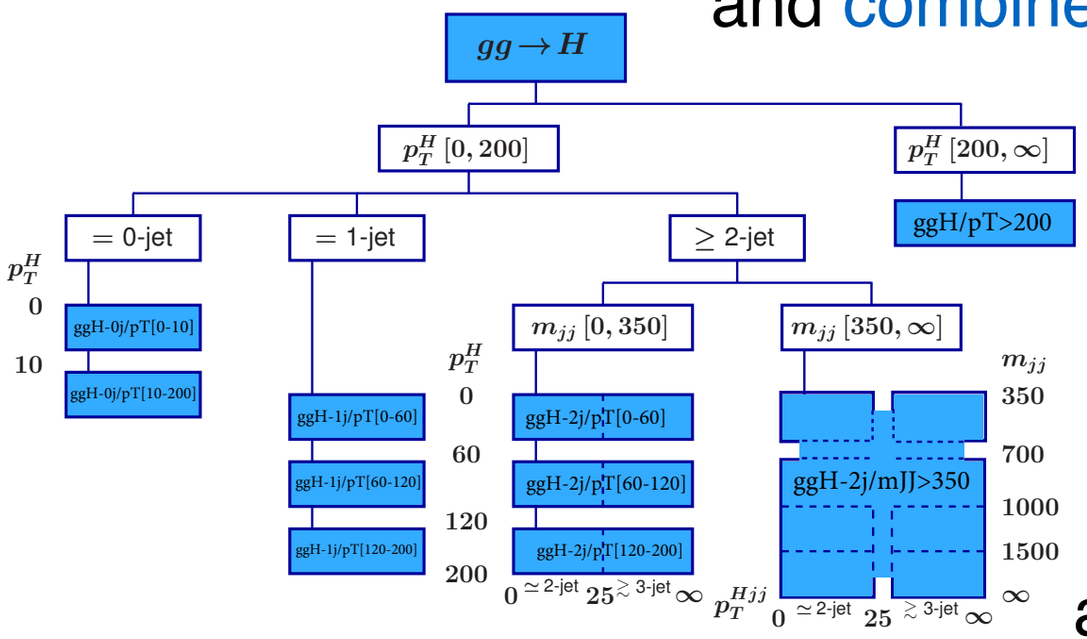


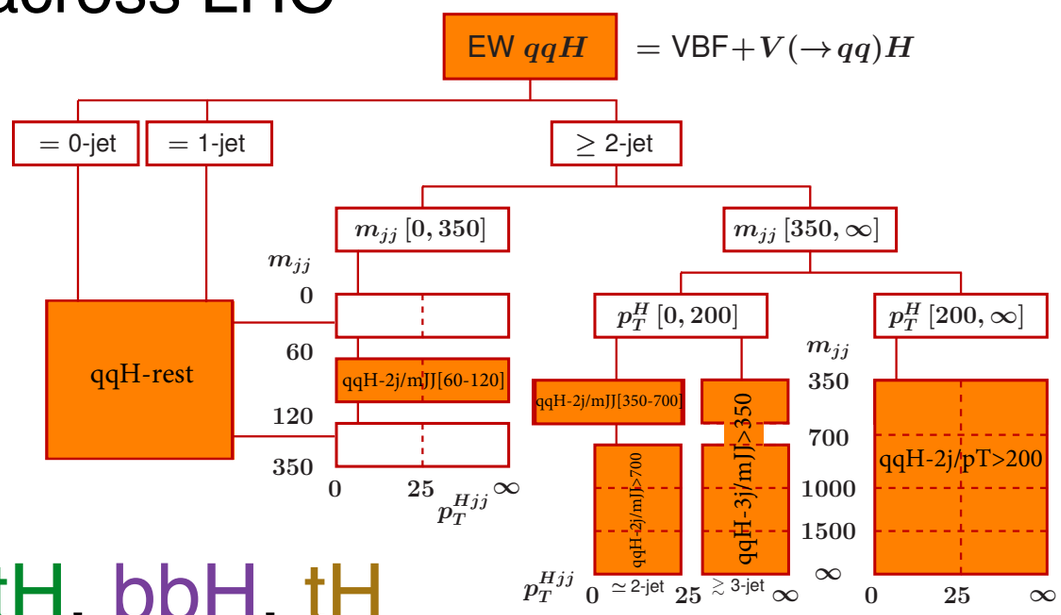
H: couplings (full Run2)





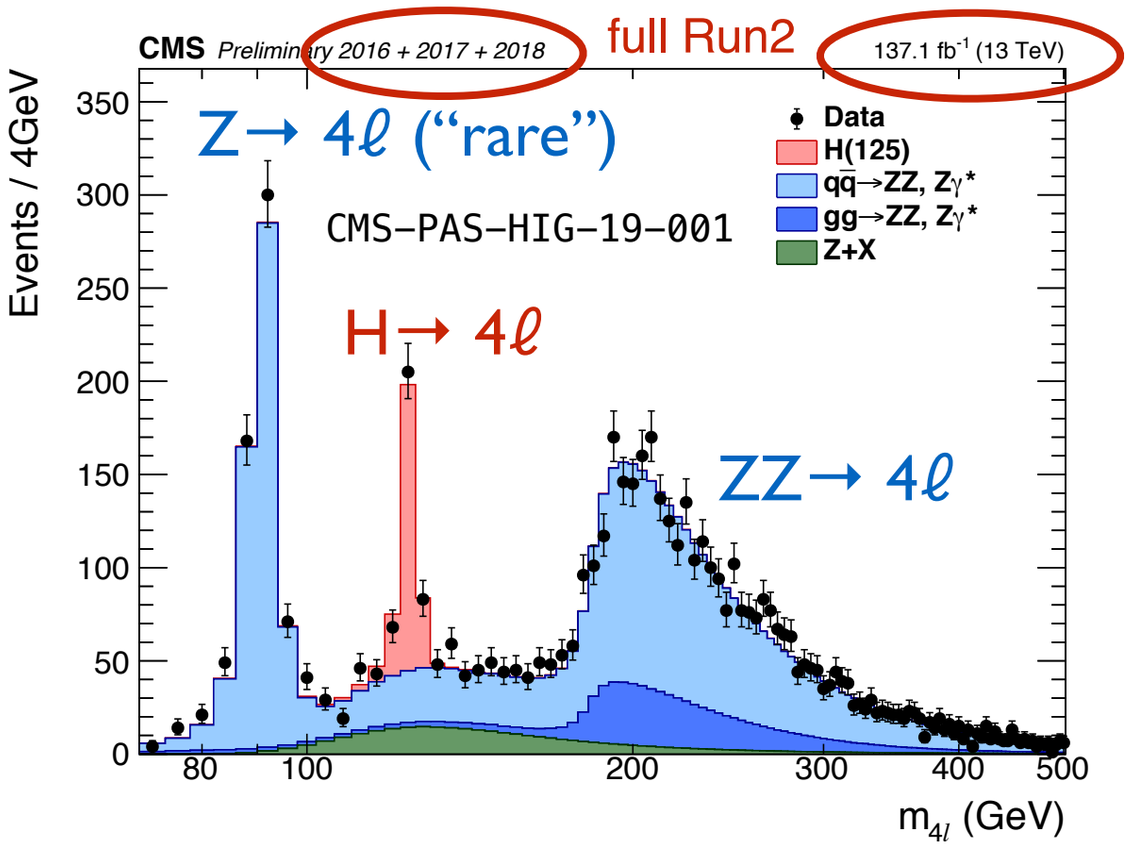
STXS s1.1: a new standard to communicate H data from LHC to Pheno colleagues and combine, analyze across LHC

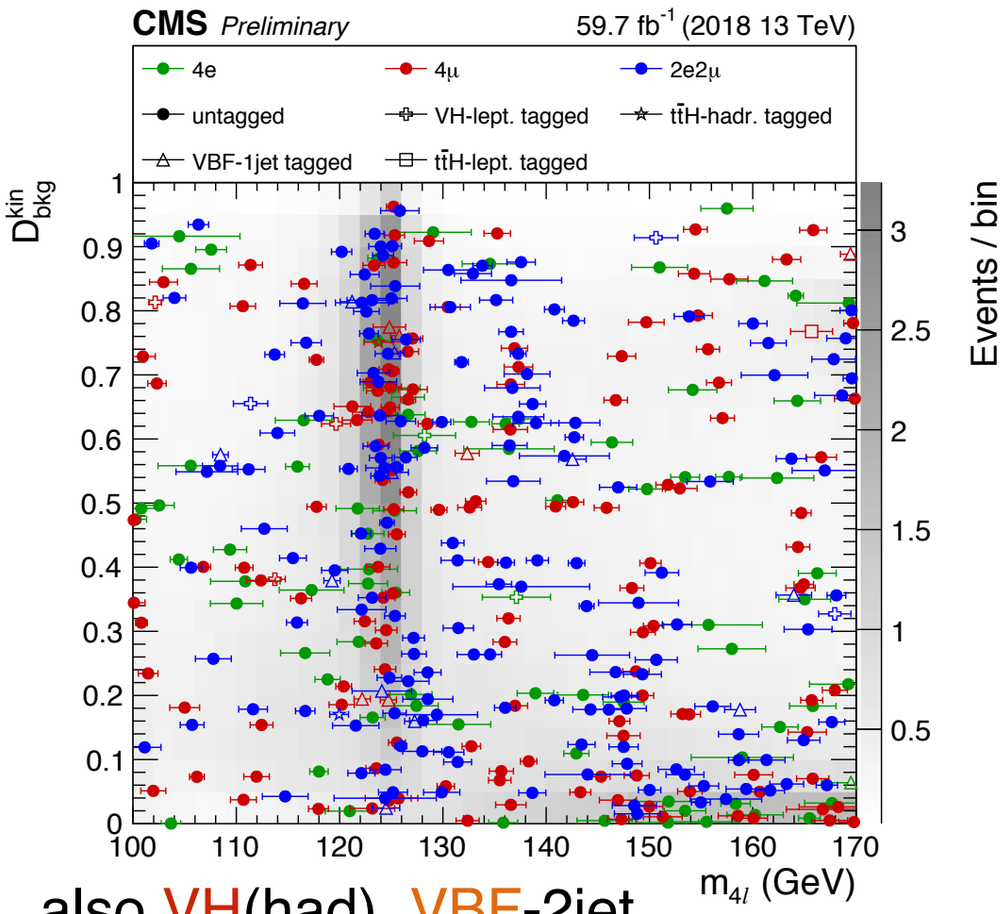




also VH, ttH, bbH, tH

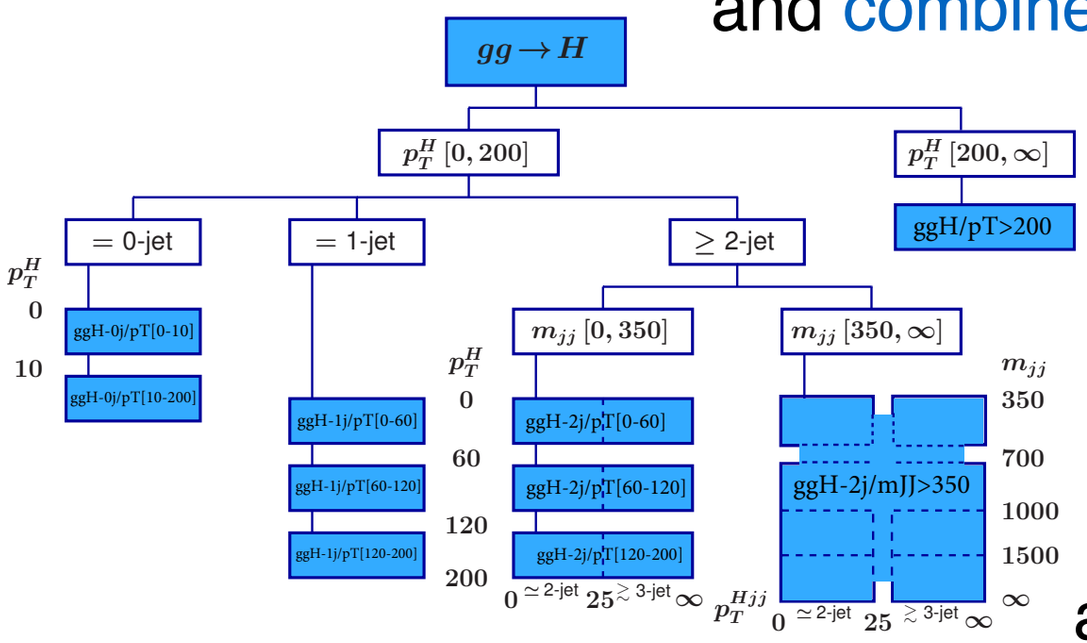
H: couplings (full Run2)

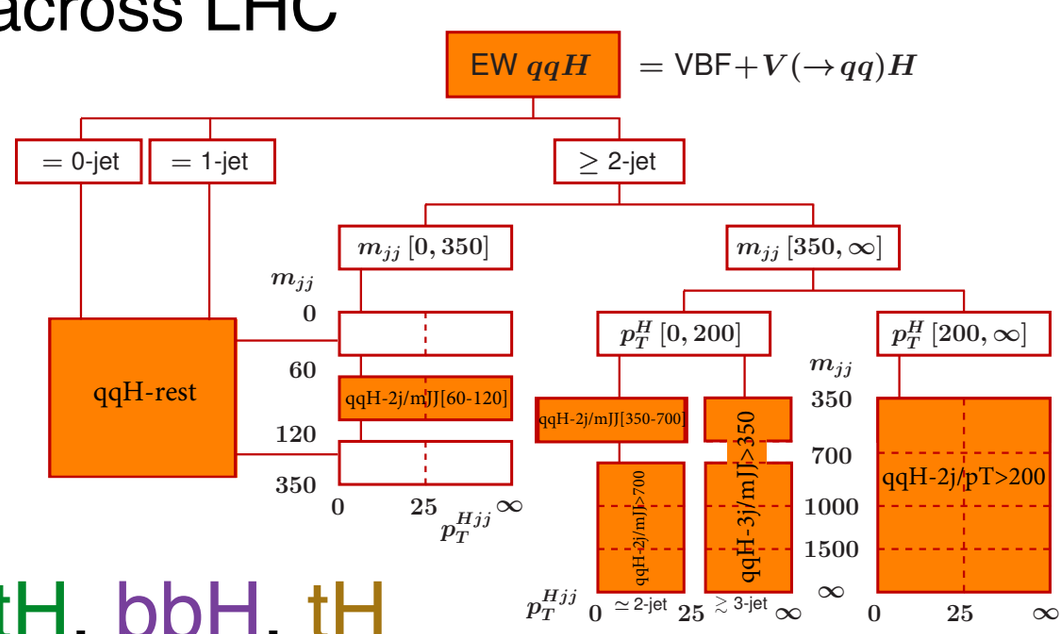




also VH(had), VBF-2jet

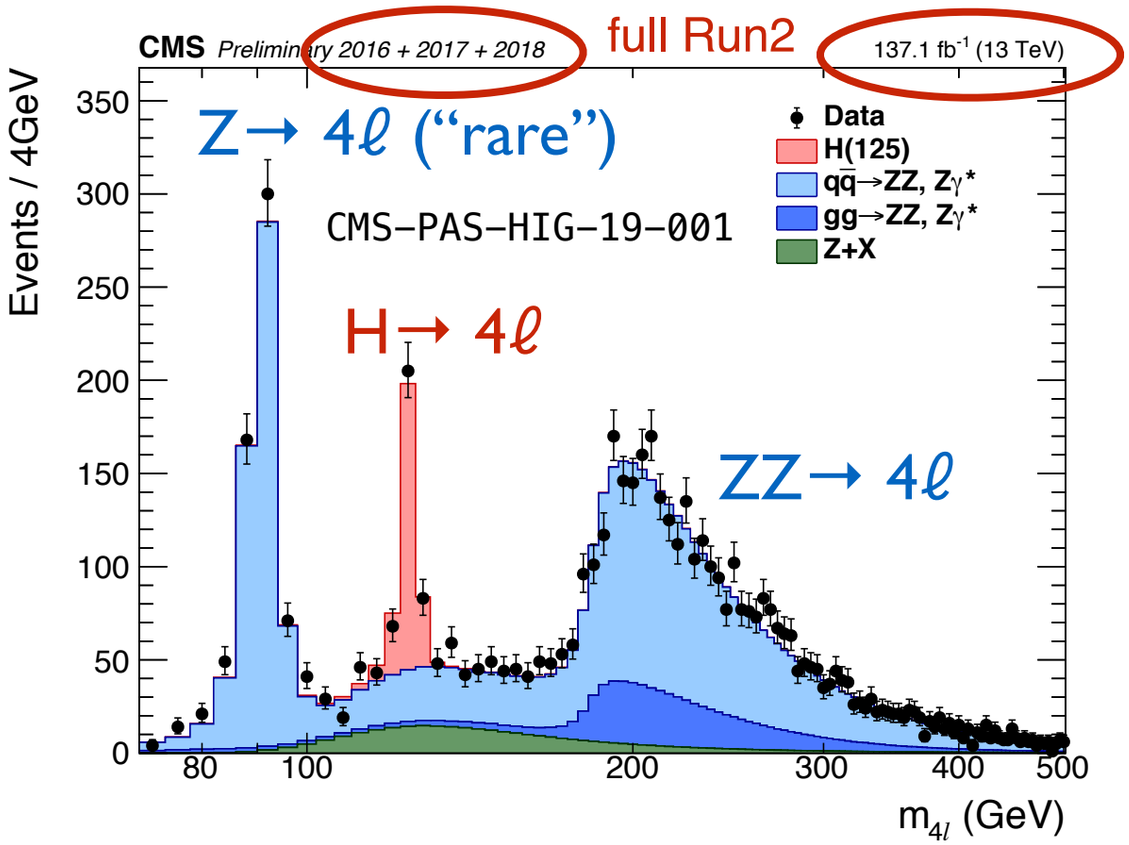
STXS s1.1: a new standard to communicate H data from LHC to Pheno colleagues and combine, analyze across LHC

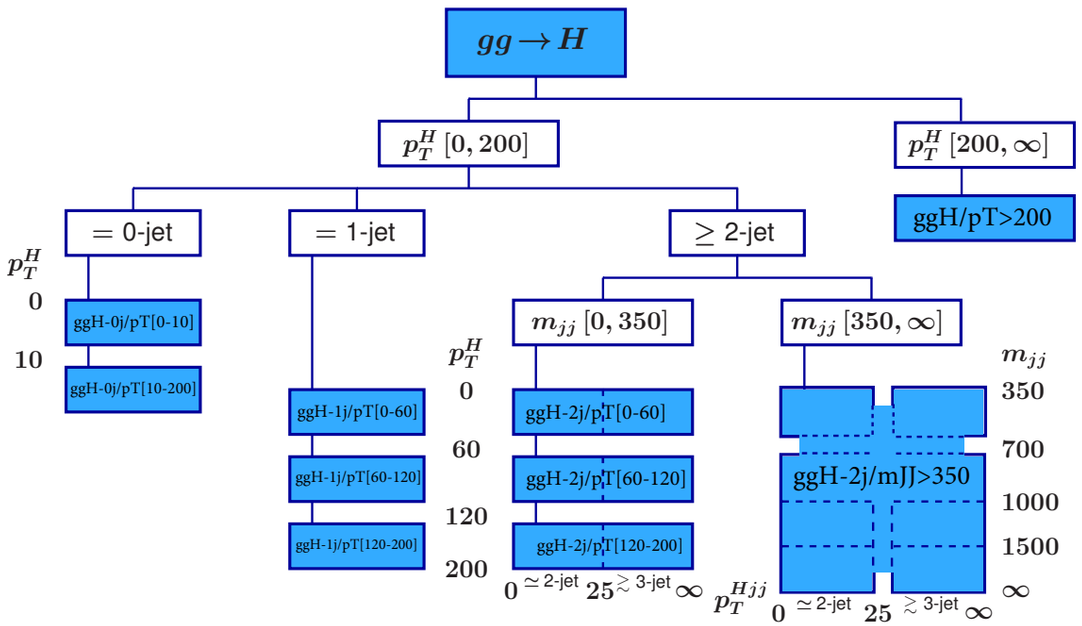


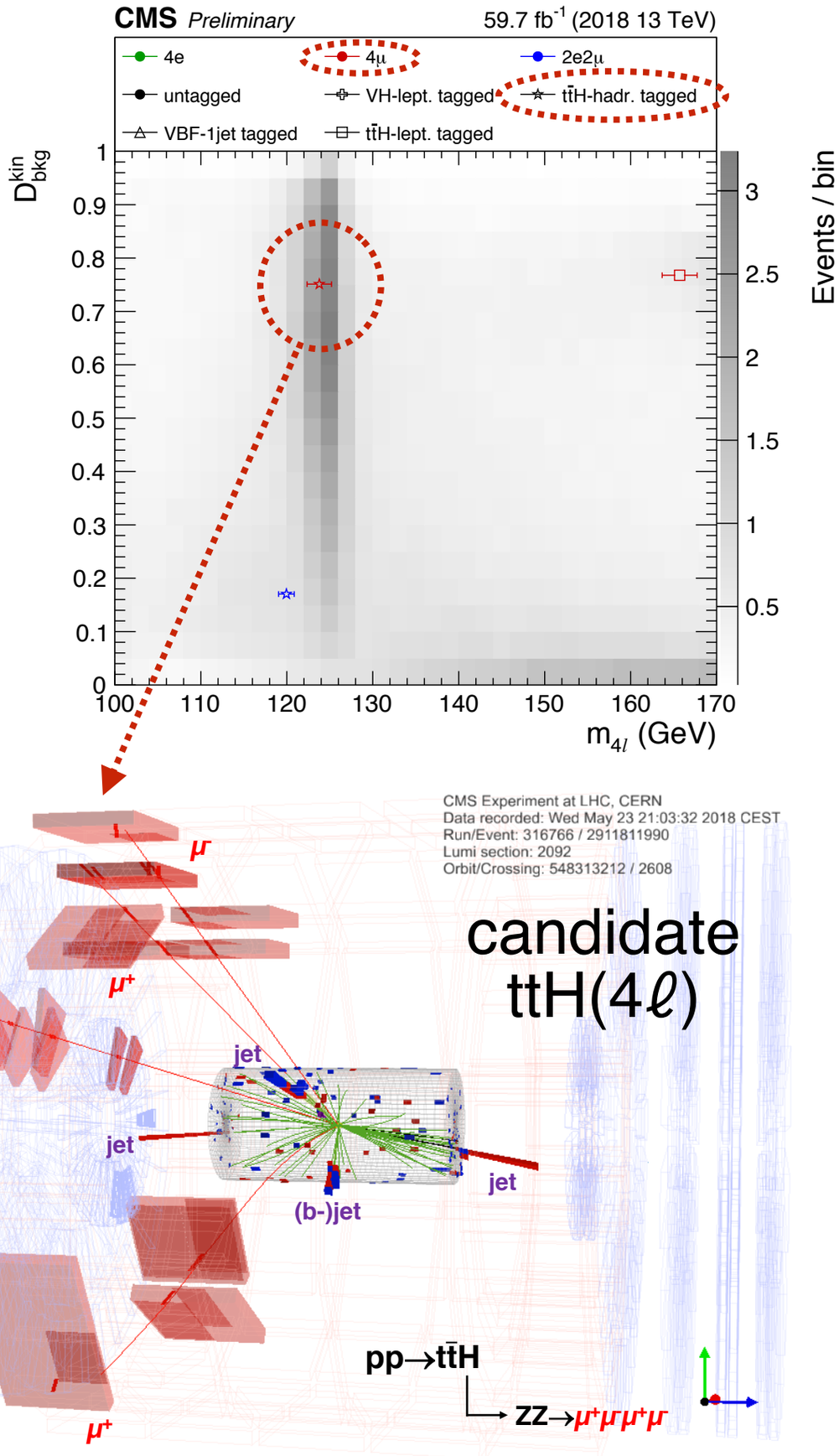


also VH, ttH, bbH, tH

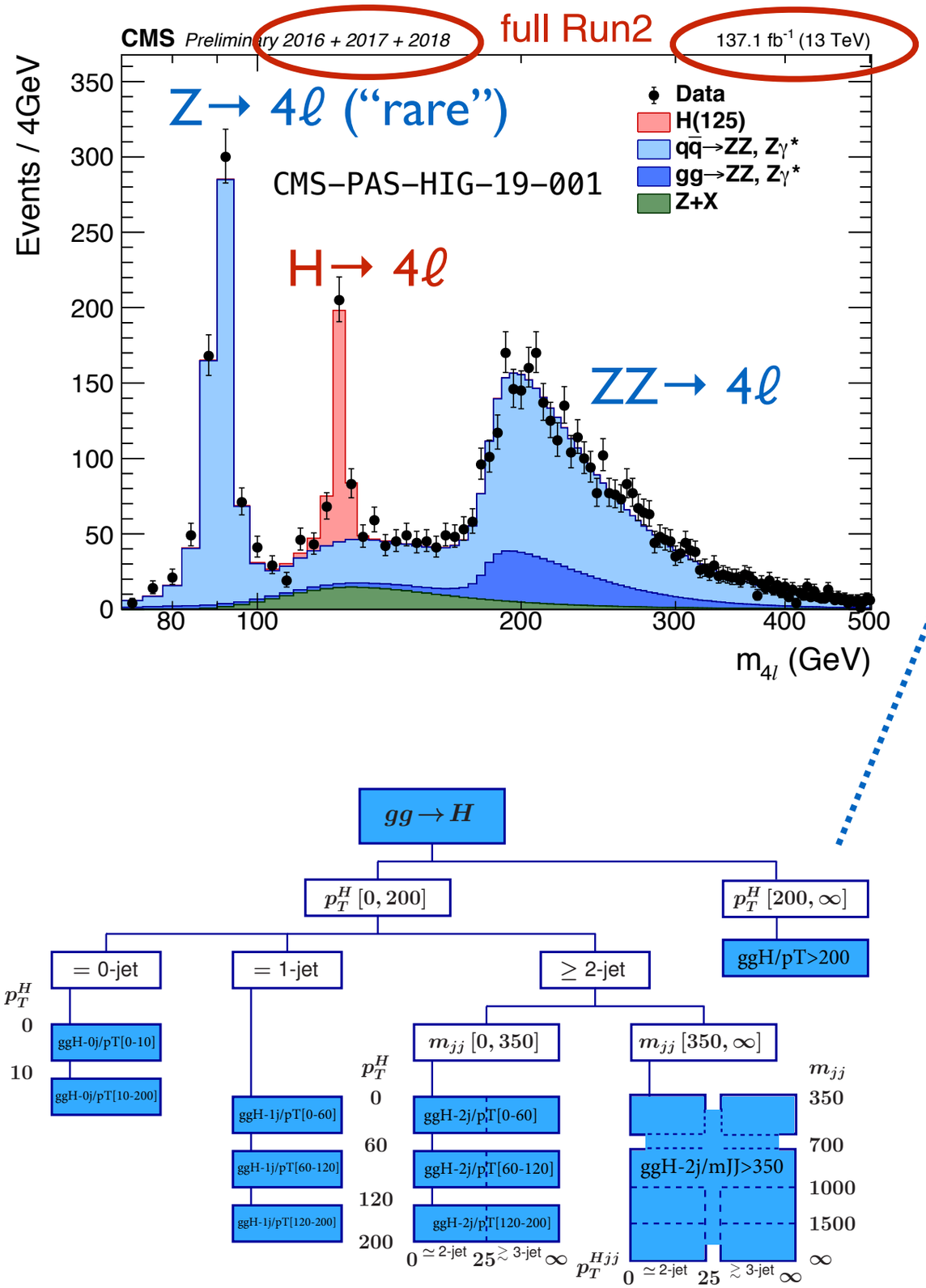
H: couplings (full Run2)

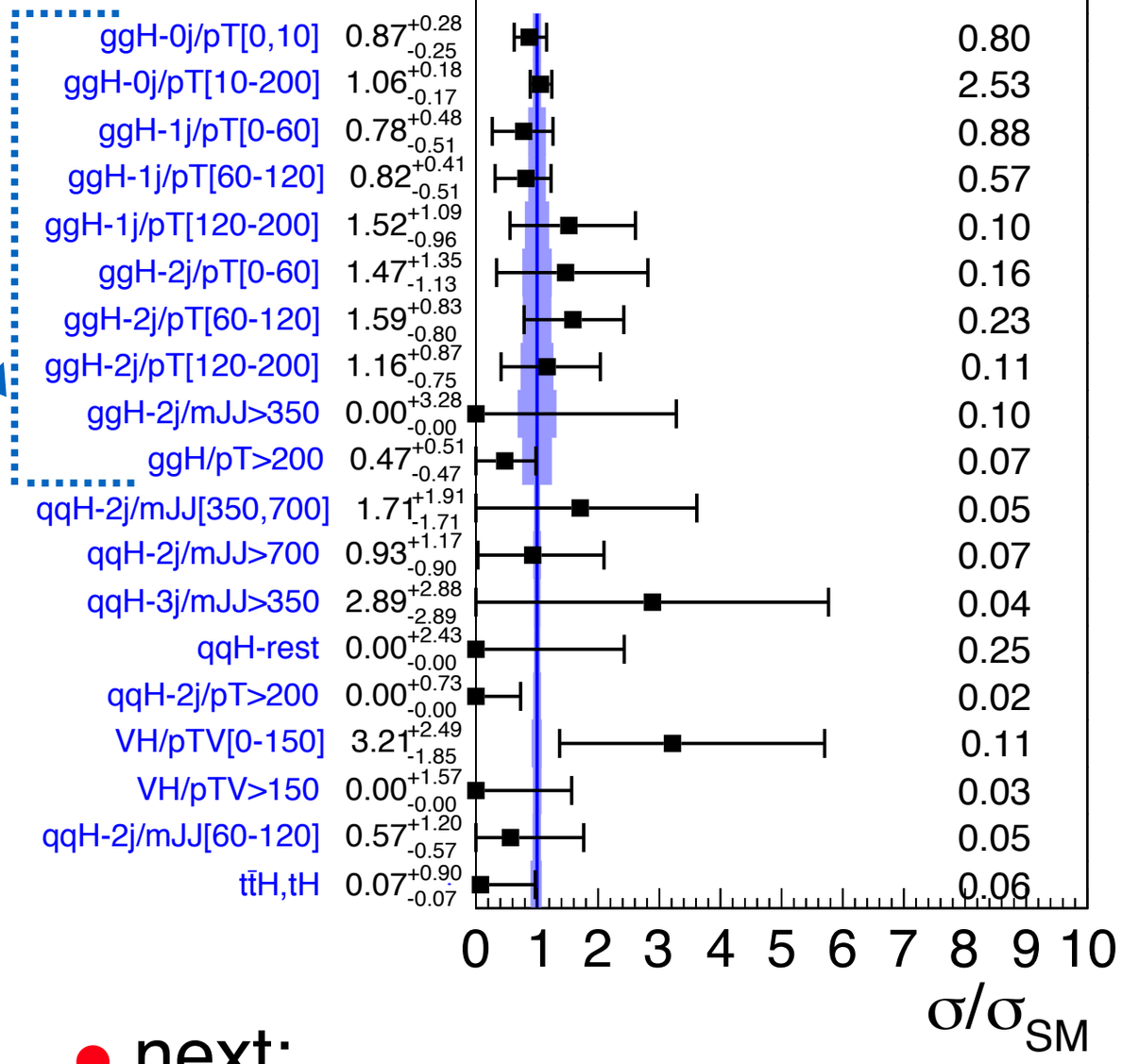






H: couplings





- next:

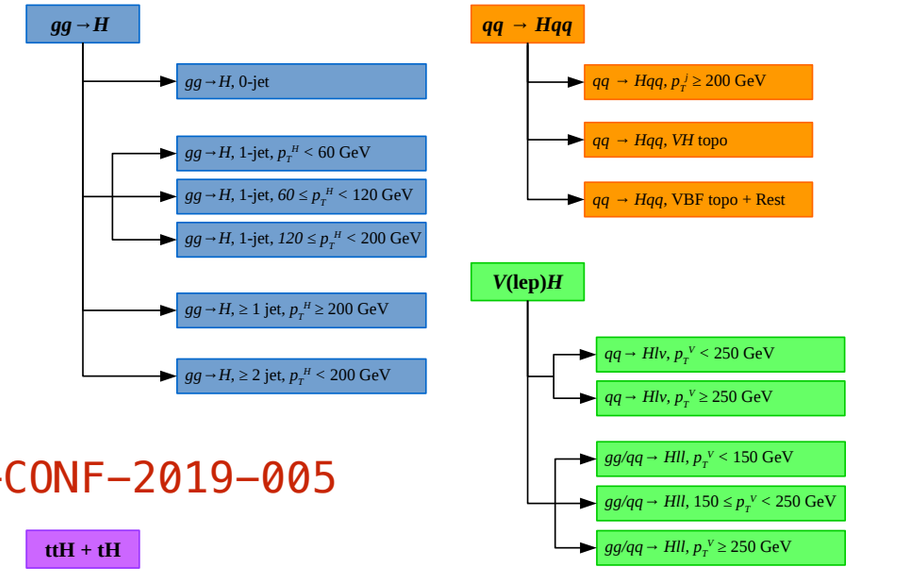
— detailed property measurements

— most power in combination

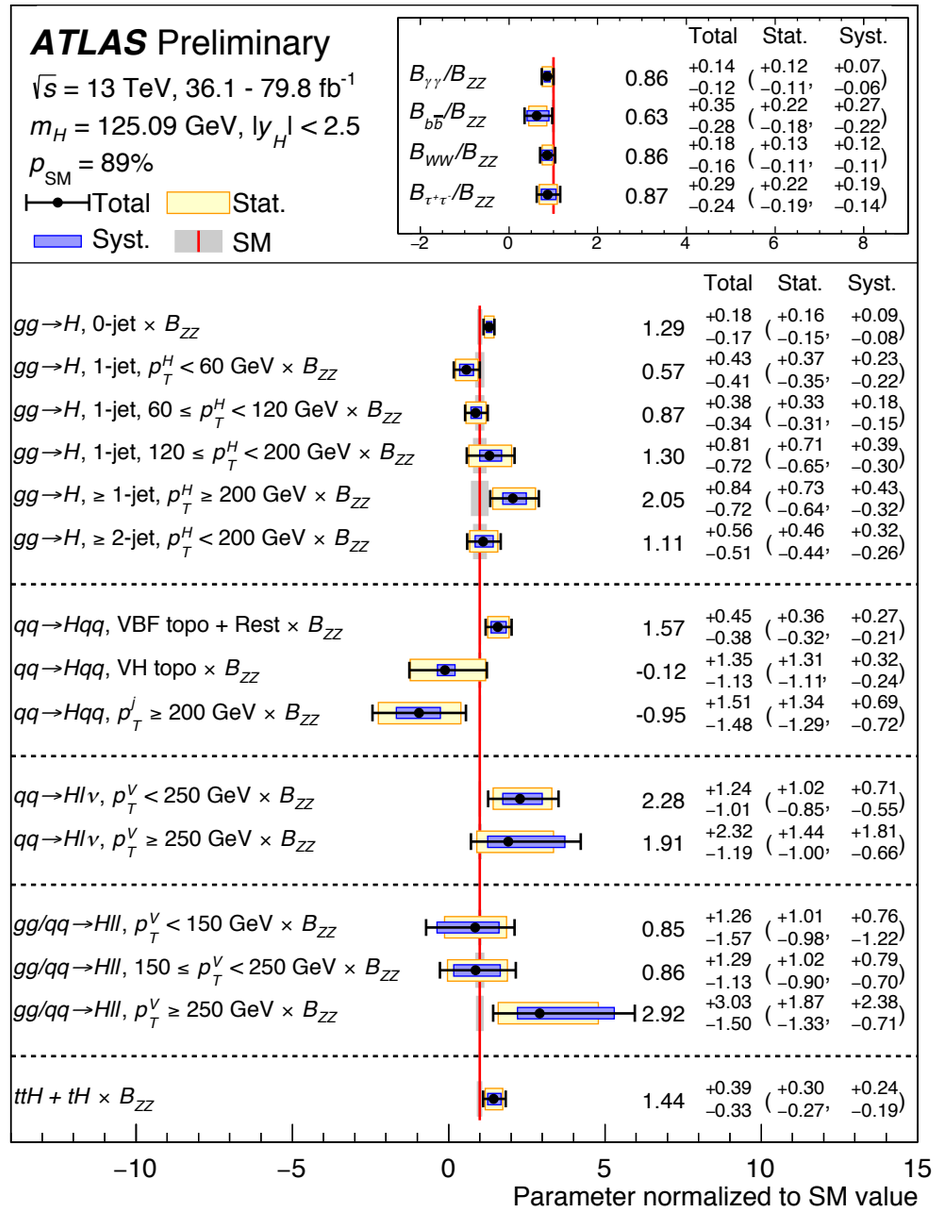
H: couplings

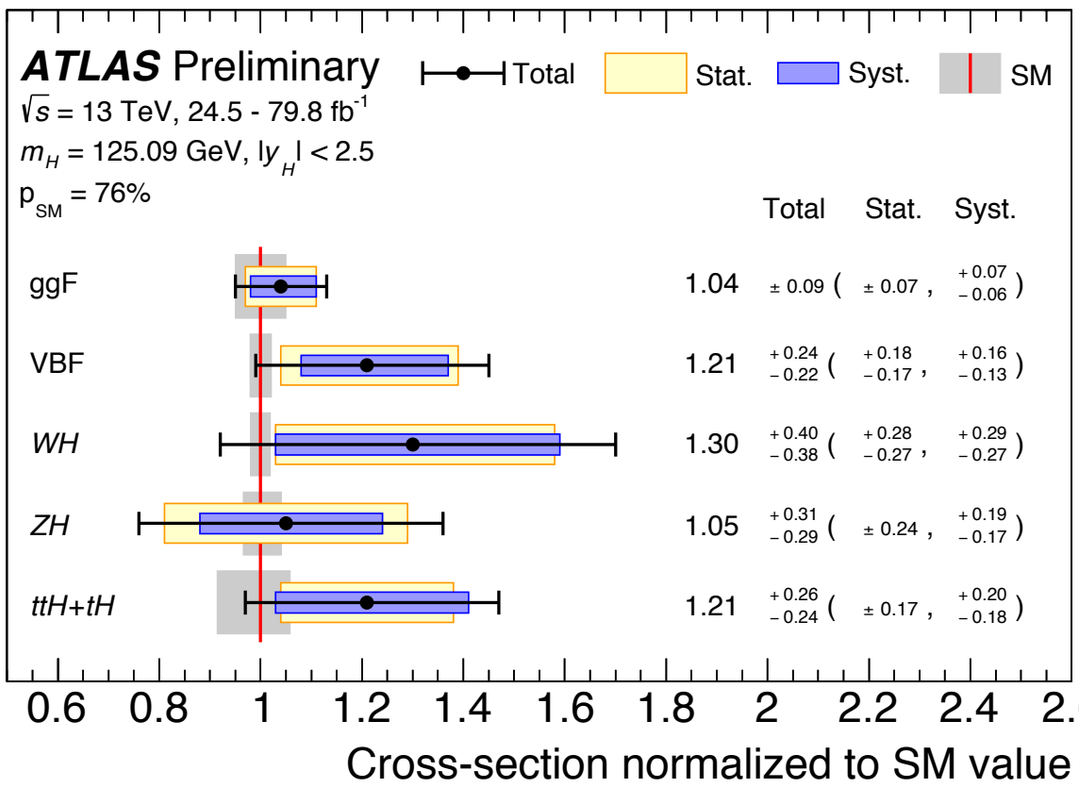
- ATLAS combination 2015+2016+(2017) data:

Analysis	Integrated luminosity (fb^{-1})
$H \to \gamma\gamma$ (including $t\bar{t}H, H \to \gamma\gamma$)	79.8
$H \to ZZ^* \to 4\ell$ (including $t\bar{t}H, H \to ZZ^* \to 4\ell$)	79.8
$H \to WW^* \to e\nu\mu\nu$	36.1
$H \to \tau\tau$	36.1
$VH, H \to b\bar{b}$	79.8
VBF, $H \to b\bar{b}$	24.5 – 30.6
$H \to \mu\mu$	79.8
$t\bar{t}H, H \to b\bar{b}$ and $t\bar{t}H$ multilepton	36.1
$H \to$ invisible	36.1
Off-shell $H \to ZZ^* \to 4\ell$ and $H \to ZZ^* \to 2\ell 2\nu$	36.1



ATLAS-CONF-2019-005





obs. (exp.)

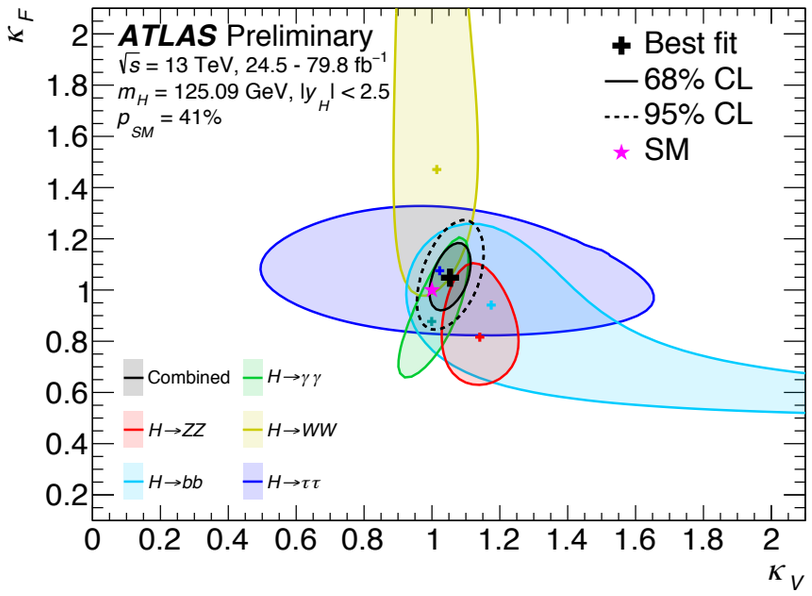
6.5σ (5.3σ)

5.3σ (4.7σ)

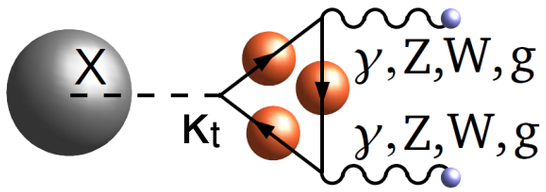
5.8σ (5.4σ)

H: couplings

- ATLAS-CONF-2019-005



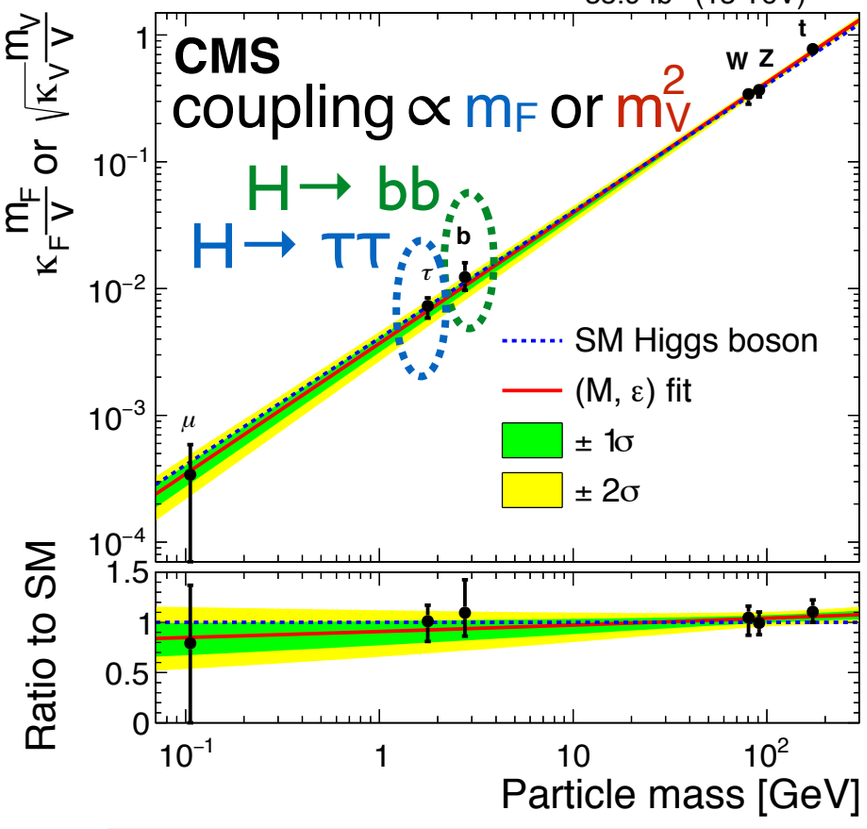
Resolved coupling modifiers



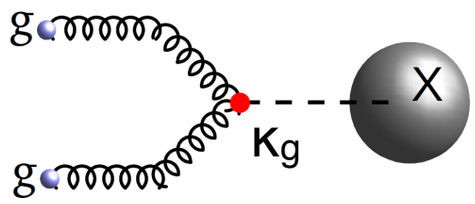
$\mathscr{L} \sim |D_\mu \varphi|^2$

$\mathscr{L} \sim \psi_i y_{ij} \psi_j \varphi$

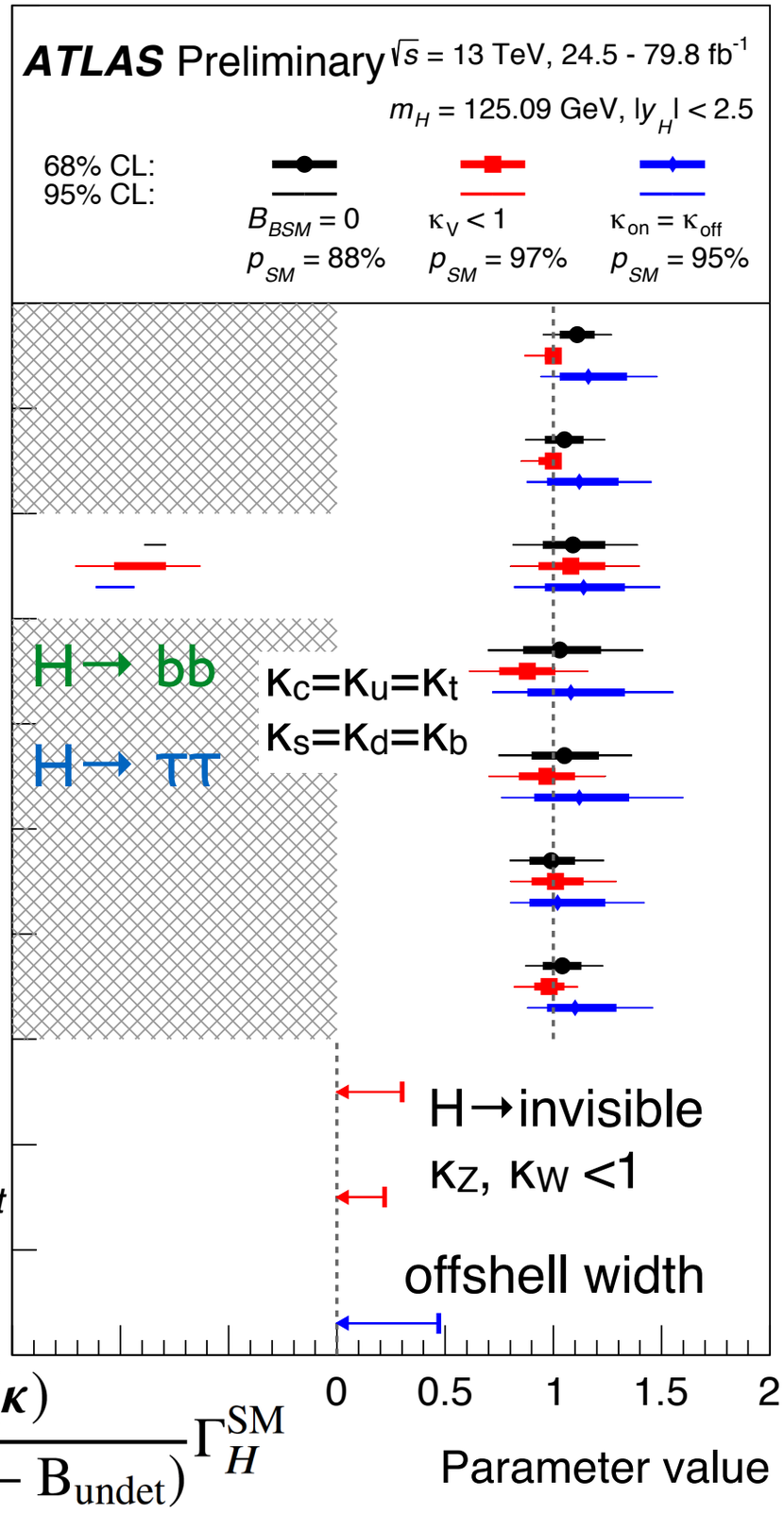
- CMS arXiv:1809.10733



Effective coupling modifier



κ_Z κ_W κ_t κ_b κ_τ κ_g κ_γ B_{inv} B_{undet} B_{BSM}



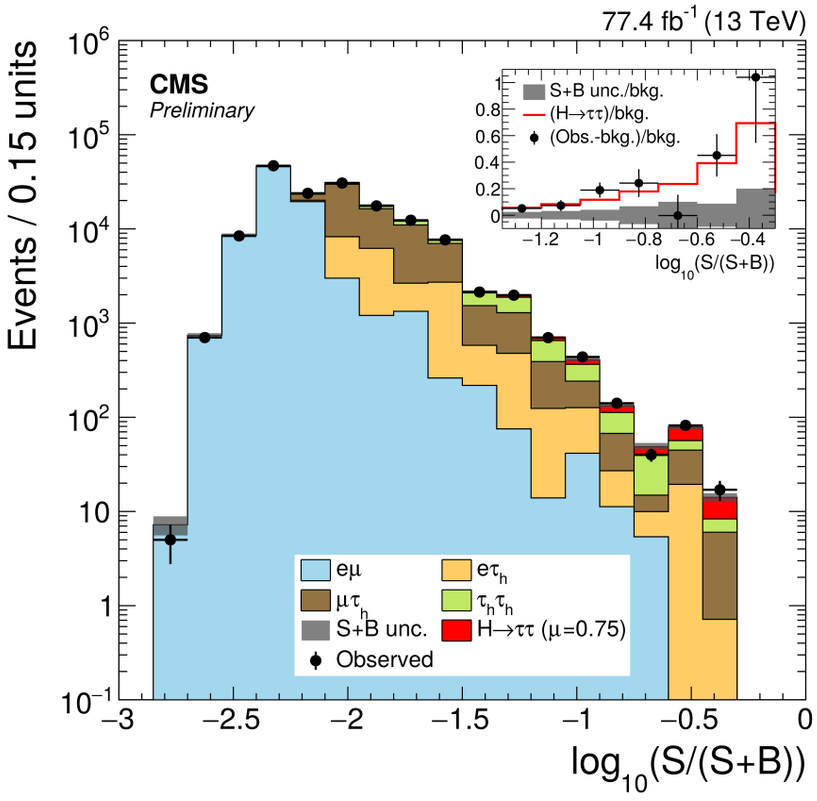
$$\Gamma_H(\boldsymbol{\kappa}, \overbrace{B_{inv}, B_{undet}}^{B_{BSM}}) = \frac{\kappa_H^2(\boldsymbol{\kappa})}{(1 - B_{inv} - B_{undet})} \Gamma_H^{SM}$$

H: couplings to b and τ

H→ ττ

- CMS-PAS-HIG-18-032 (STXS)

4.7(6.6)σ μ=0.75±0.18
(2016+2017 data)



- ATLAS arXiv:1811.08856

6.4(5.4)σ $\mu=1.09^{+0.35}_{-0.30}$
(Run1+2015/16 data)

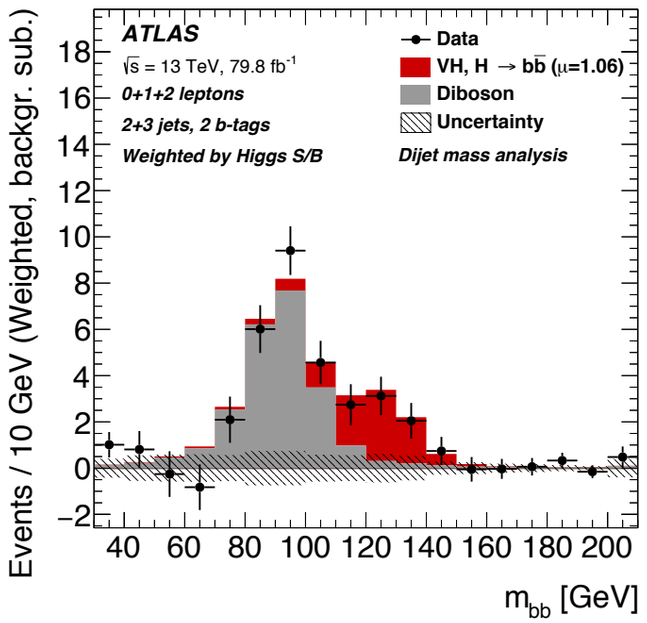
- CMS arXiv:1708.00373

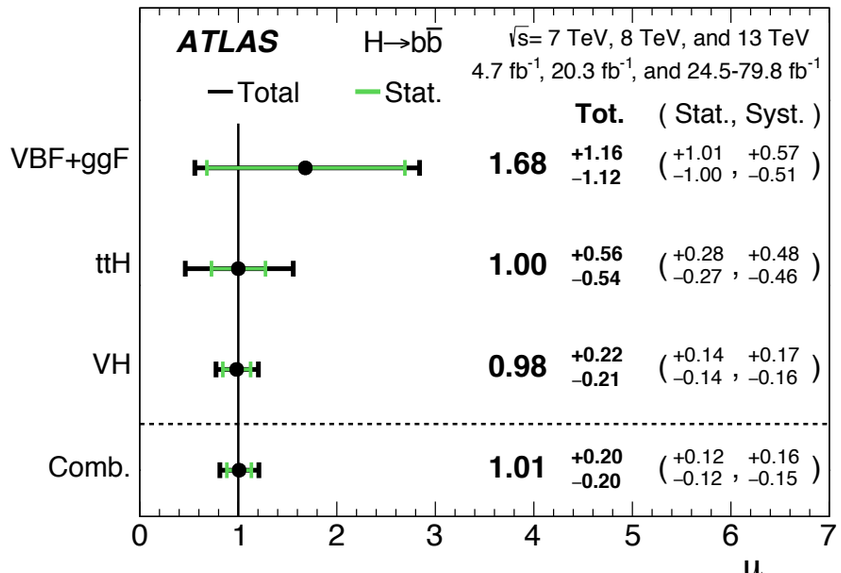
5.9(5.9)σ μ=0.98±0.18
(Run1+2016 data)

H→ bb

- ATLAS arXiv:1808.08238

5.4(5.5)σ μ=1.01±0.20
(Run1+2015/16 data)

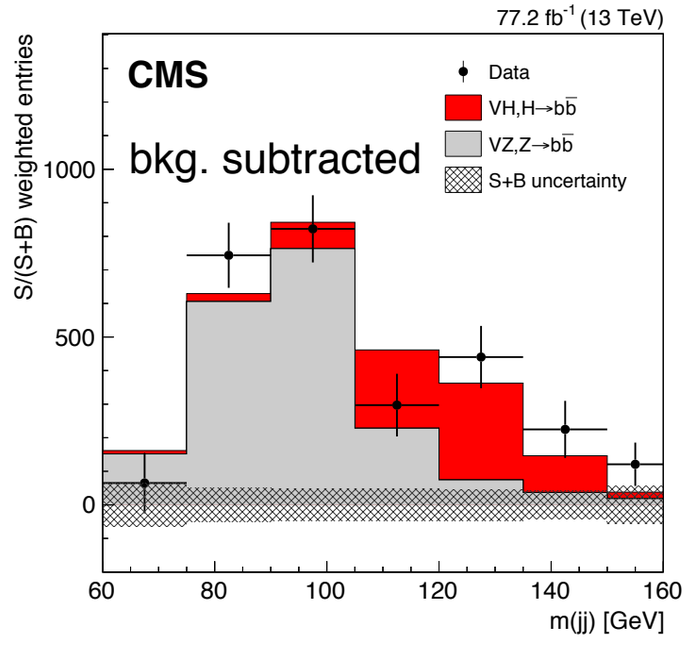


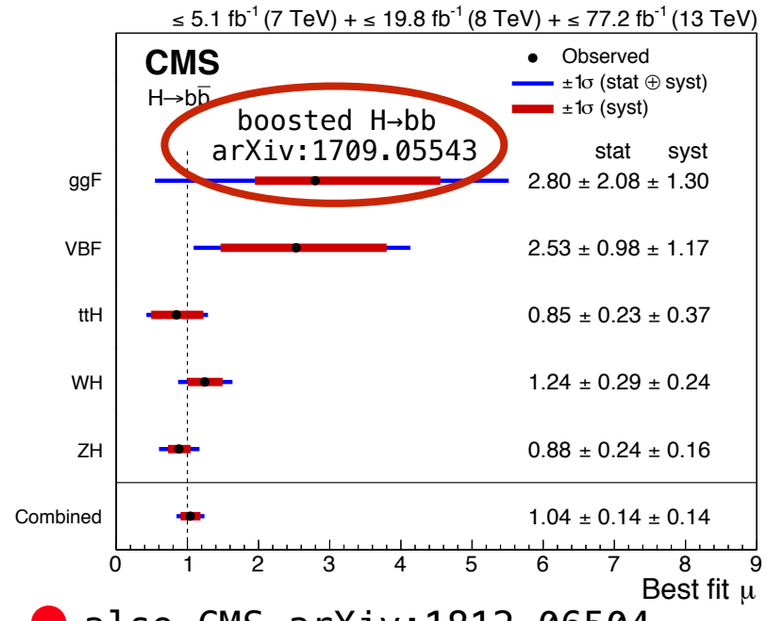


- also ATLAS arXiv:1903.04618

- CMS arXiv:1808.08242

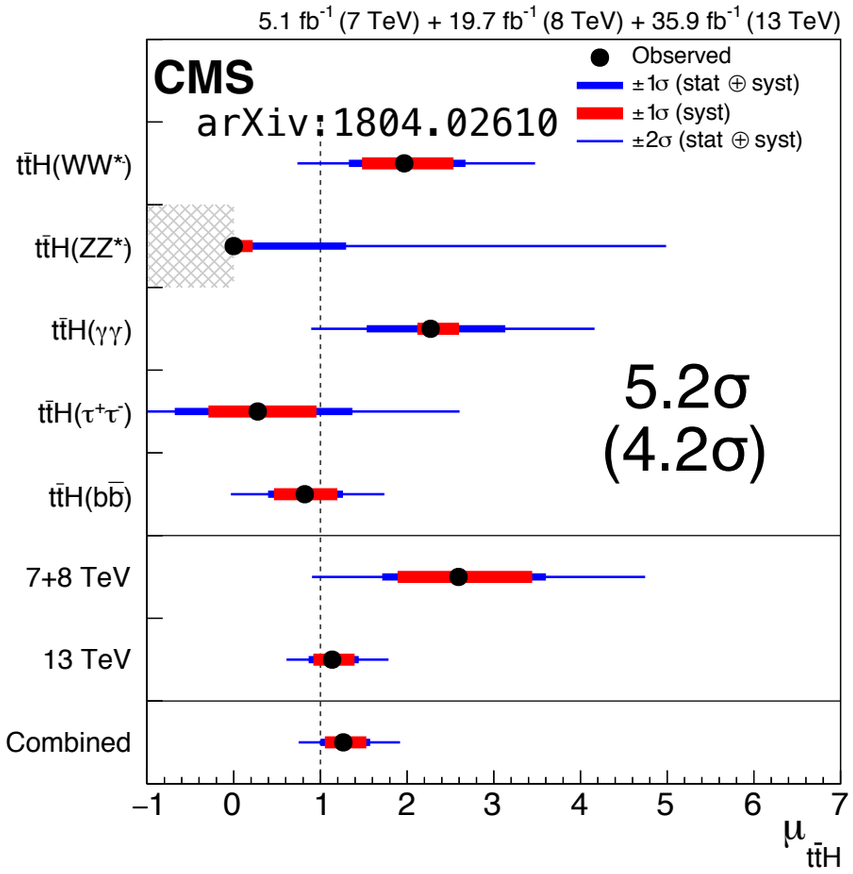
5.6(5.5)σ μ=1.04±0.20
(Run1+2016/17 data)

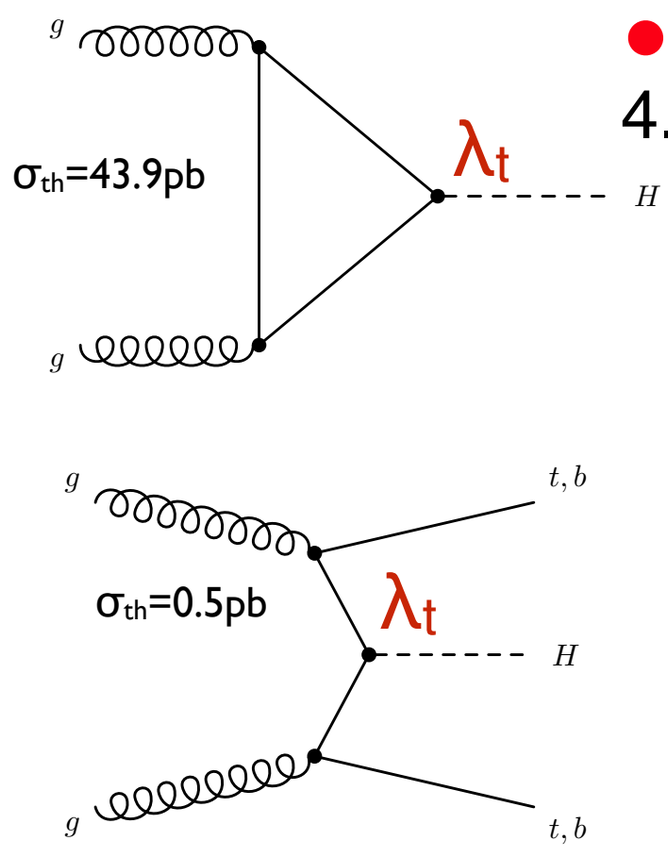




- also CMS arXiv:1812.06504

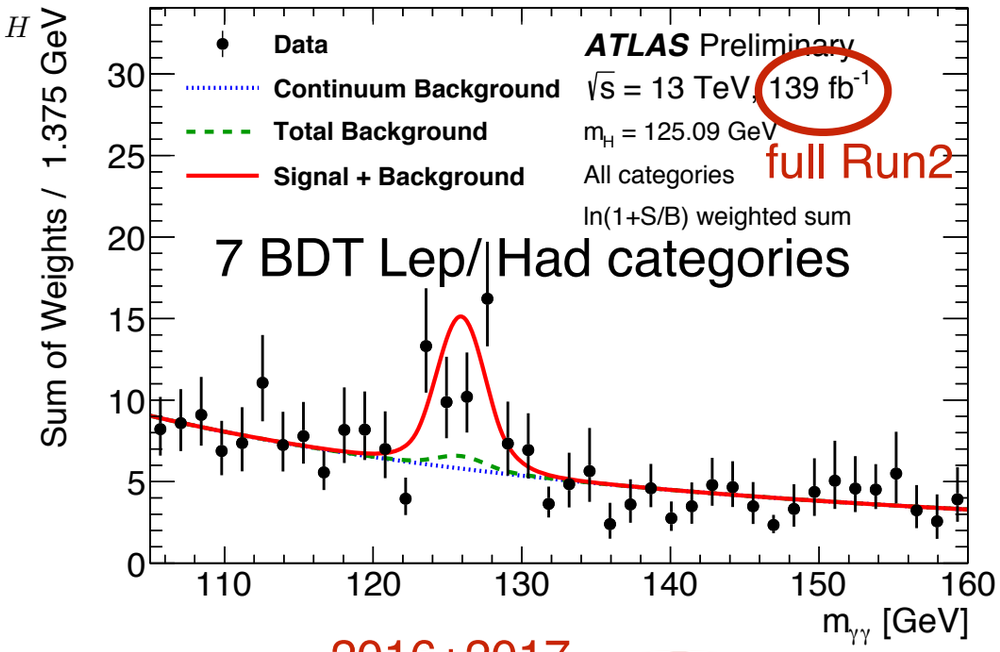
ttH: couplings (including full Run2)



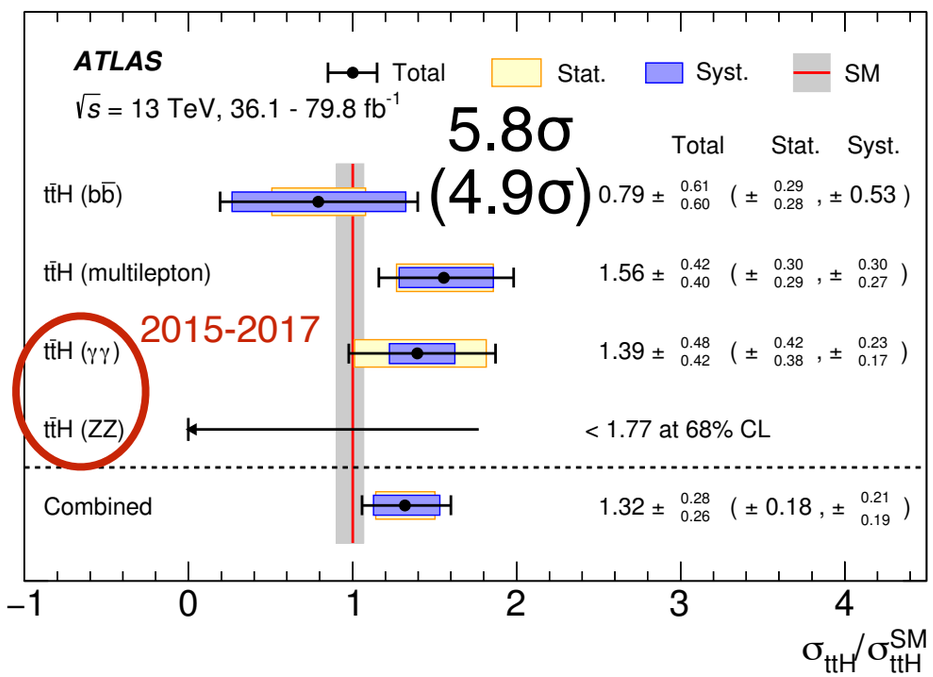


- ATLAS-CONF-2019-004

4.9(4.2)σ ttH(γγ) $\mu_{ttH}=1.38^{+0.41}_{-0.36}$



ATLAS arXiv:1806.00425



- CMS-PAS-HIG-18-018

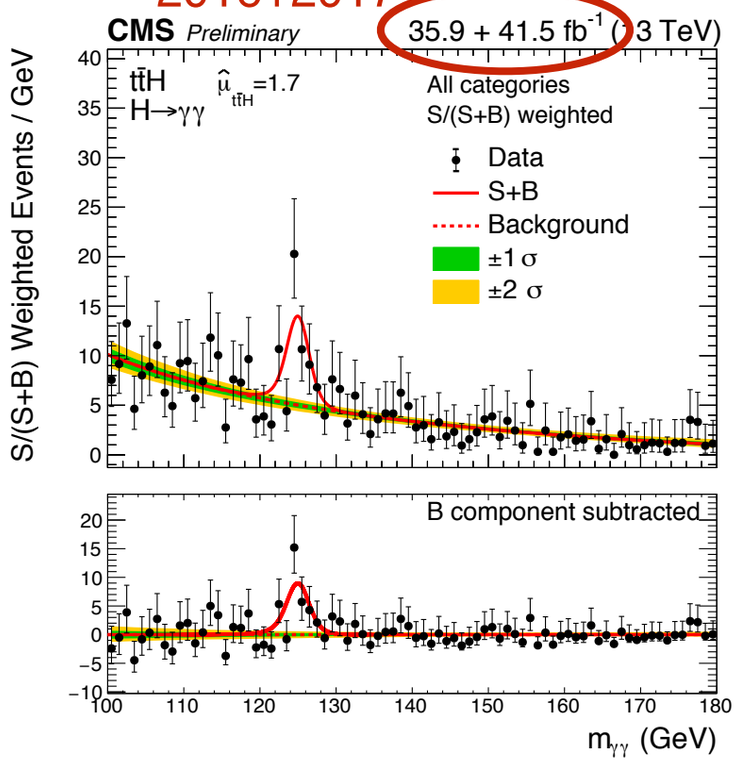
4.1(2.7)σ ttH(γγ)

$\mu_{ttH}=1.7^{+0.6}_{-0.5}$

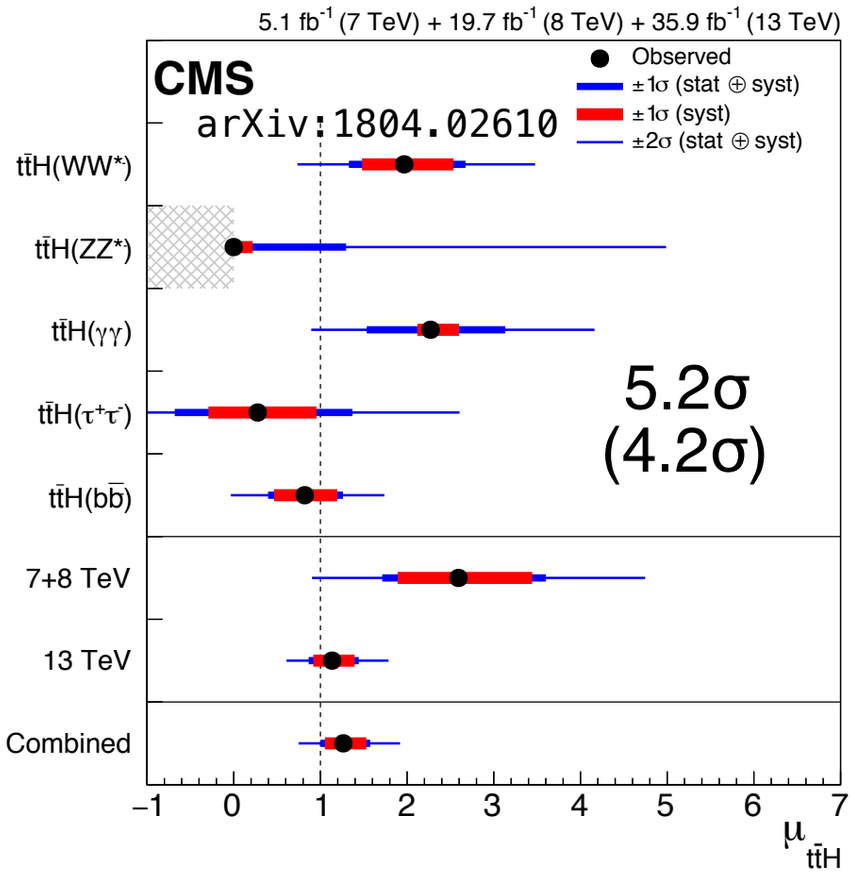
- ATLAS + CMS

ttH in a single channel

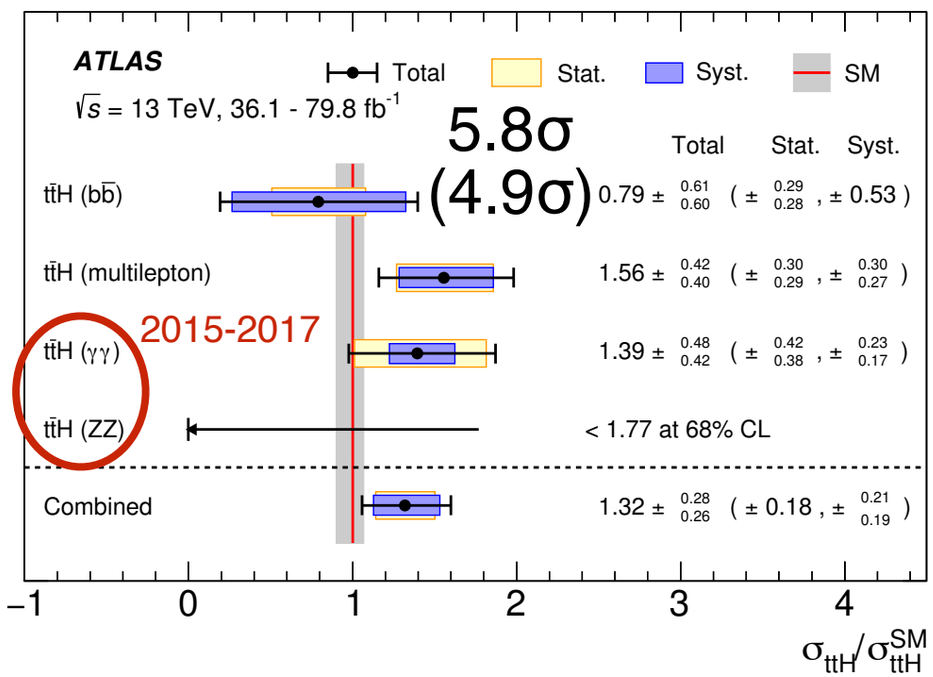
2016+2017

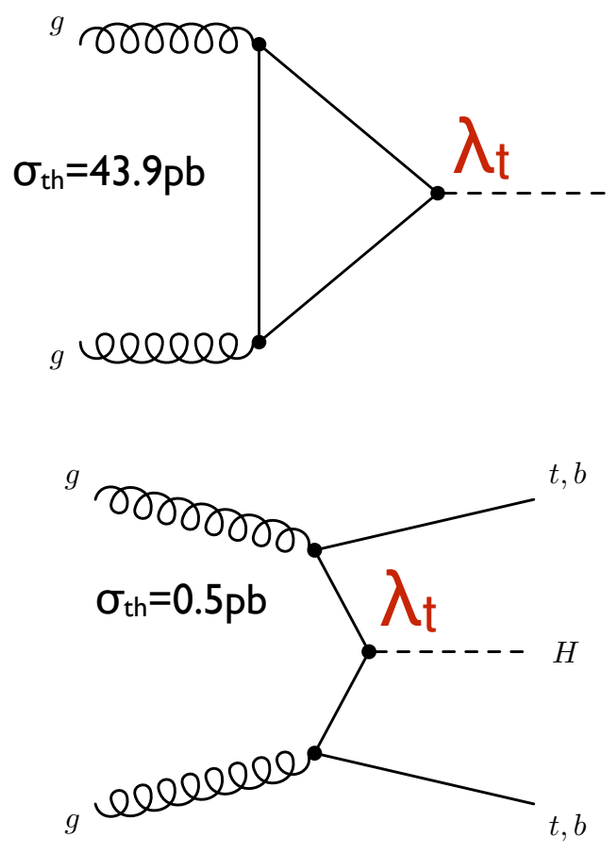


ttH: couplings (including full Run2)



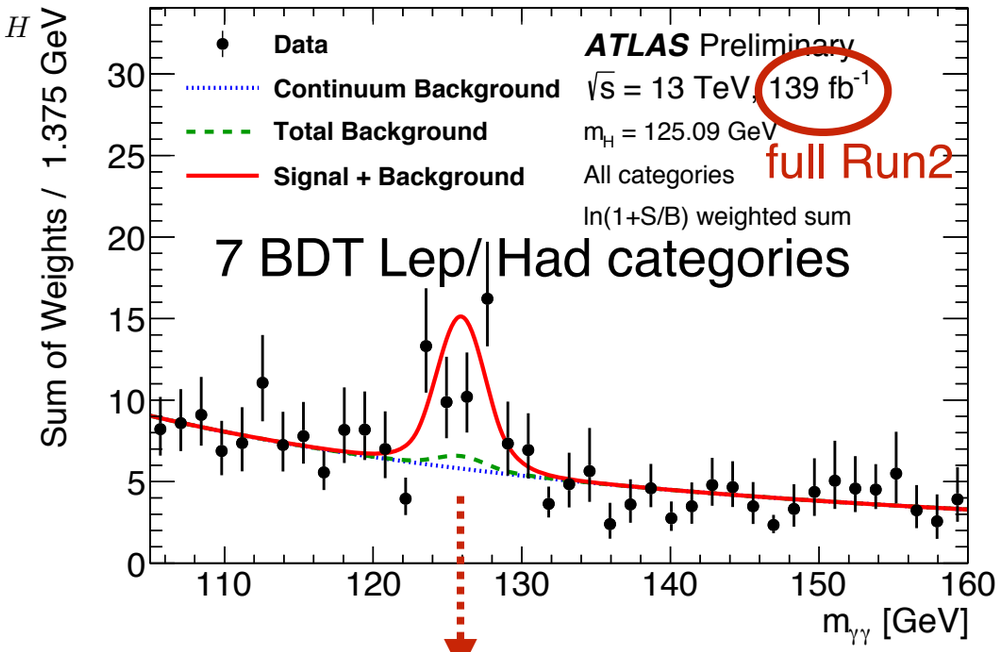
ATLAS arXiv:1806.00425

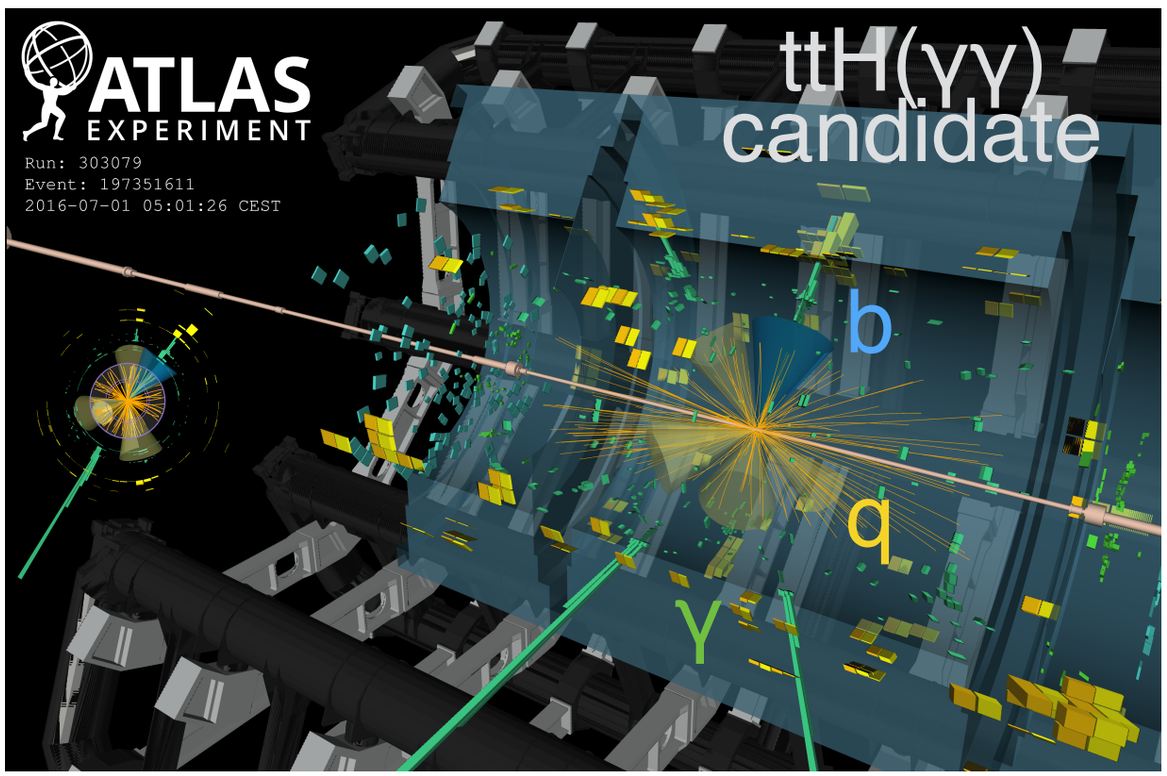




● ATLAS-CONF-2019-004

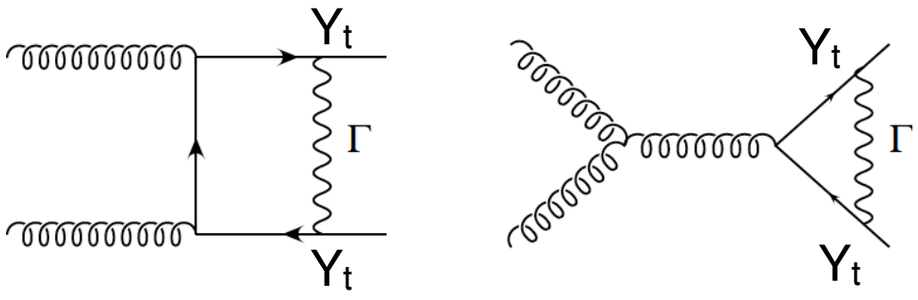
4.9(4.2)σ ttH(γγ) $\mu_{ttH}=1.38^{+0.41}_{-0.36}$



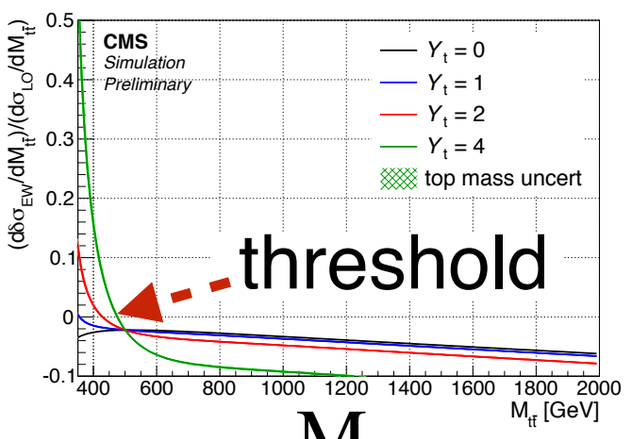


tt: couplings / cross sections

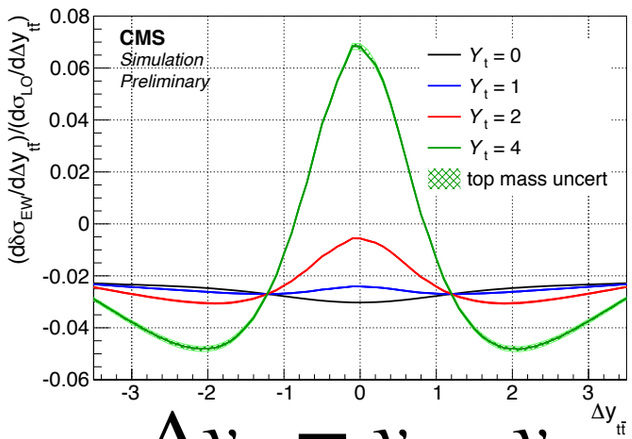
- LHC is the top factory ----▶
- constrain ttH coupling Y_t in virtual effects (Y_t=1 in SM):



EW correction / σ_{LO}



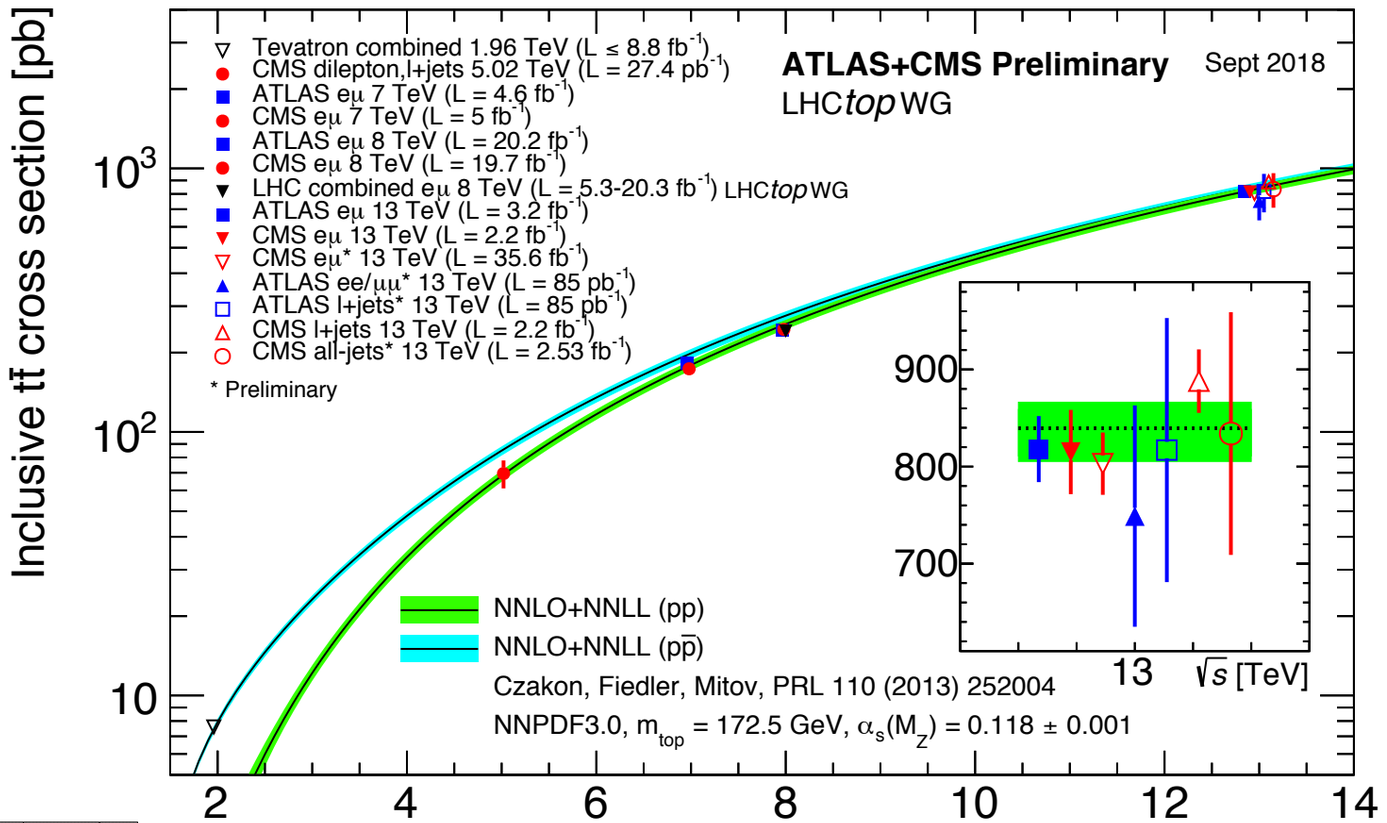
$M_{t\bar{t}}$

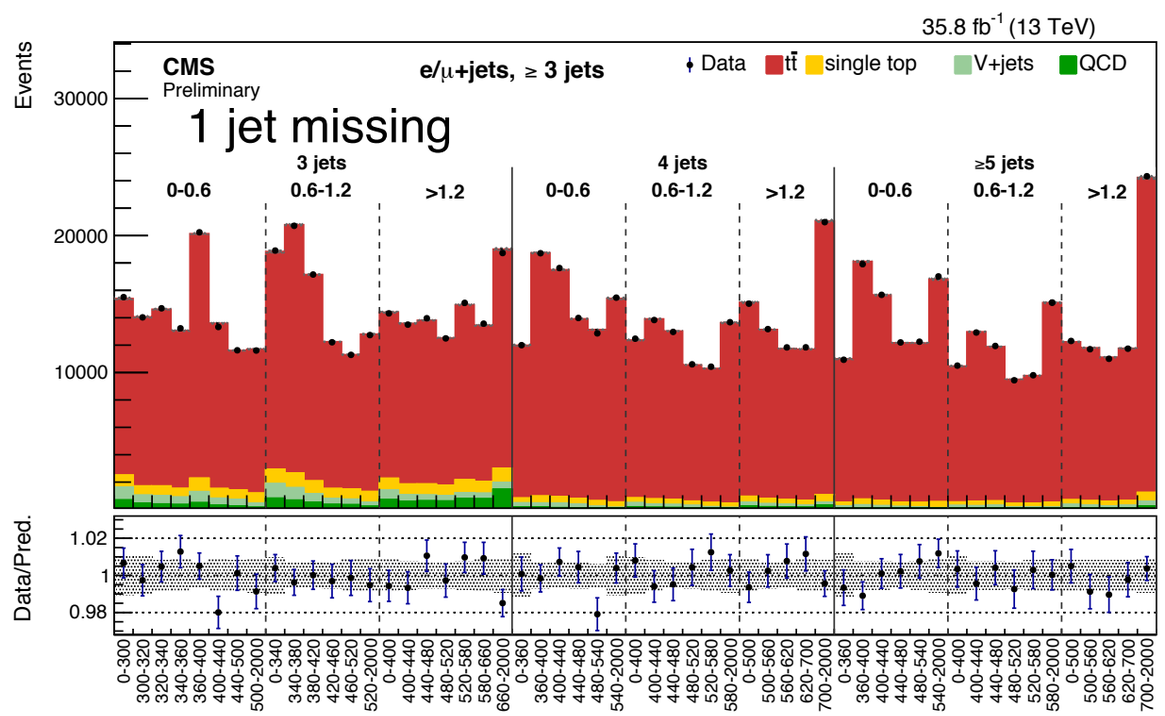


$\Delta y_{t\bar{t}} = y_t - y_{\bar{t}}$

CMS-PAS-TOP-17-004

$|Y_t| < 1.62$ at 95 % CL ◀----

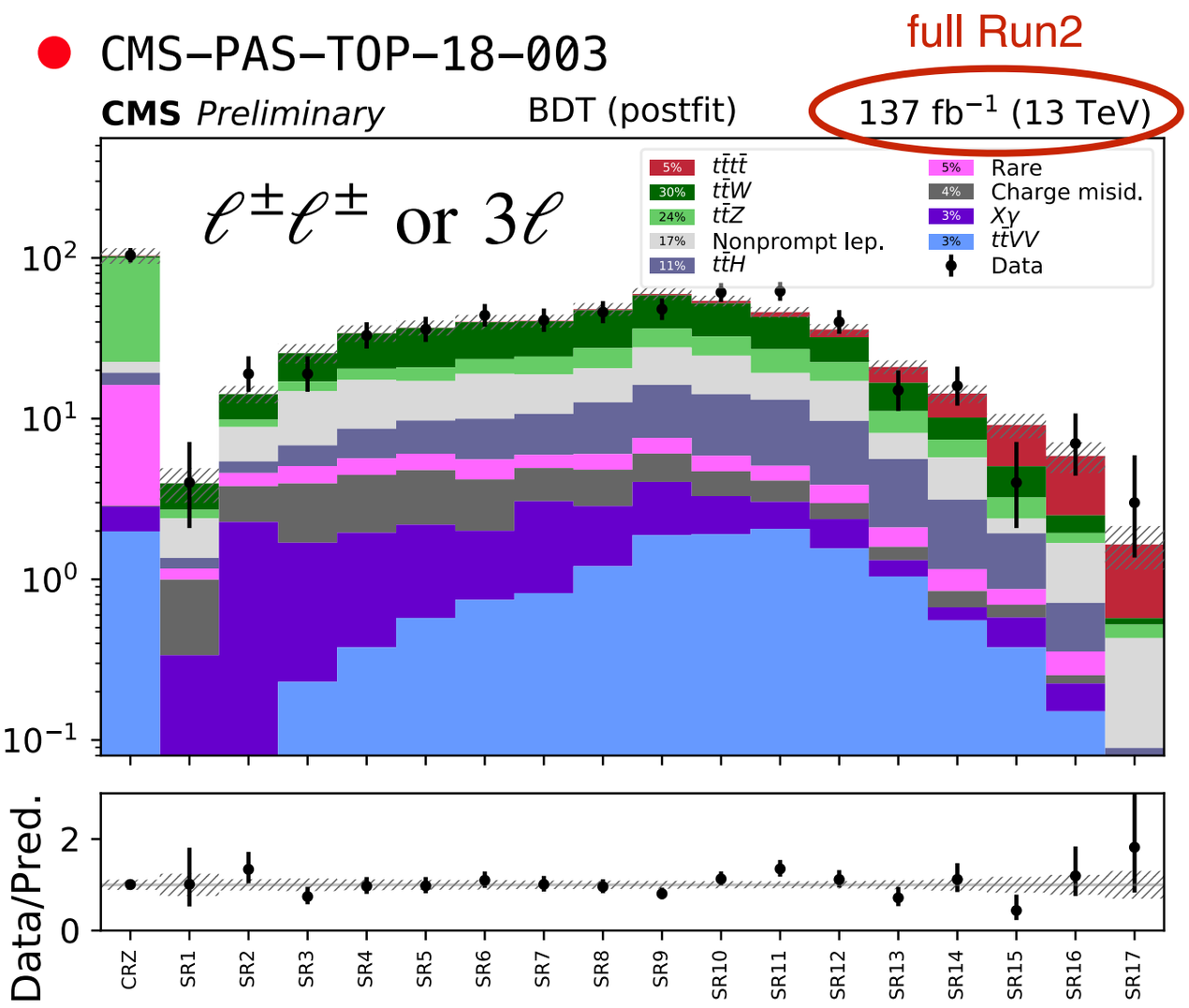




tttt: couplings / cross sections (full Run2)

tttt rare process ~10 fb at 13 TeV

- CMS-PAS-TOP-18-003



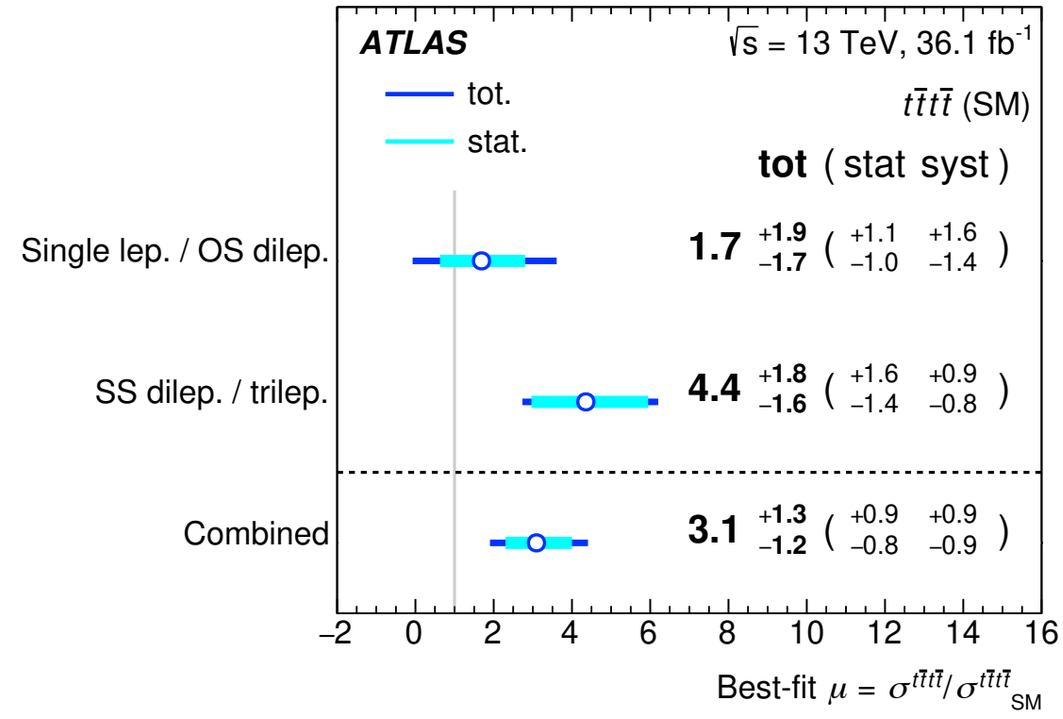
$\sigma_{t\bar{t}t\bar{t}} = 12.6^{+5.8}_{-5.2}$ fb (2.6σ)

virtual H

$\dashrightarrow |Y_t| < 1.7$ at 95 % CL

- ATLAS arXiv:1811.02305

$\sigma_{t\bar{t}t\bar{t}} = 29^{+12}_{-11}$ fb (2.8σ)



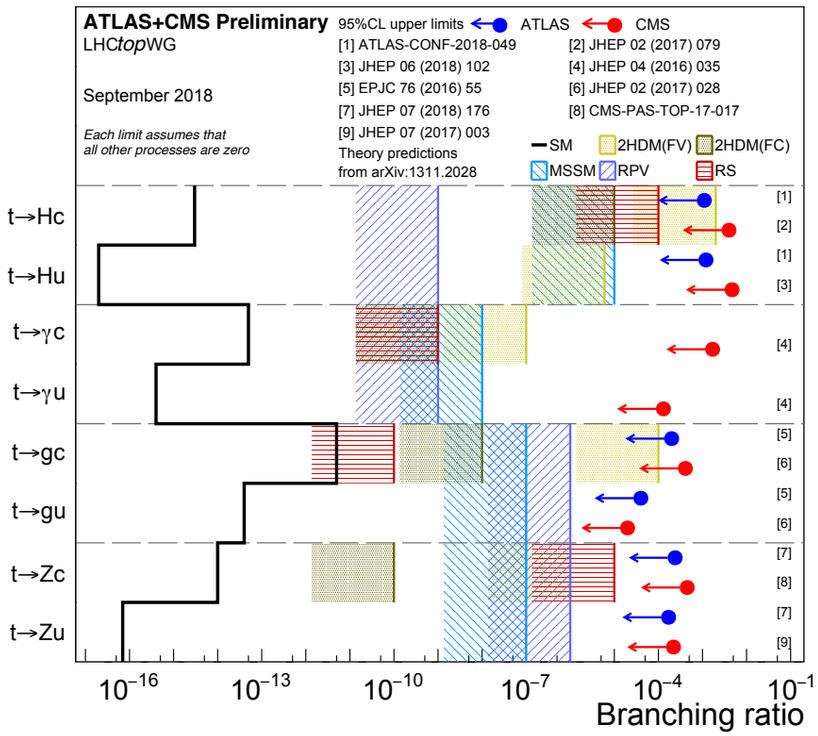
- CMS-PAS-TOP-17-019 (36 fb^{-1})

$\ell^{\pm}$ or $\ell^{+}\ell'^{-}$ ($t\bar{t}$ backgr.)

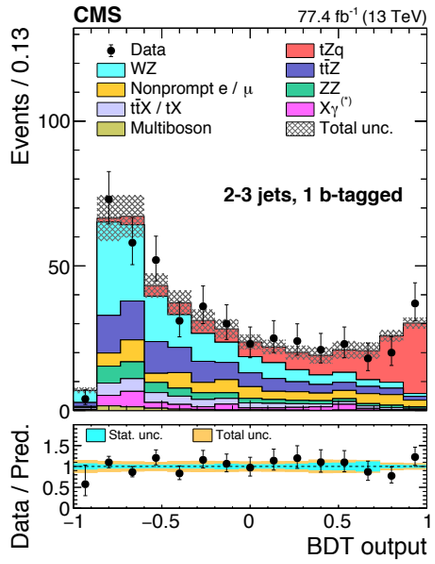
$\sigma_{t\bar{t}t\bar{t}} = 13^{+11}_{-9}$ fb (1.4σ)

top: rare/exotic processes

- limits on FCNC

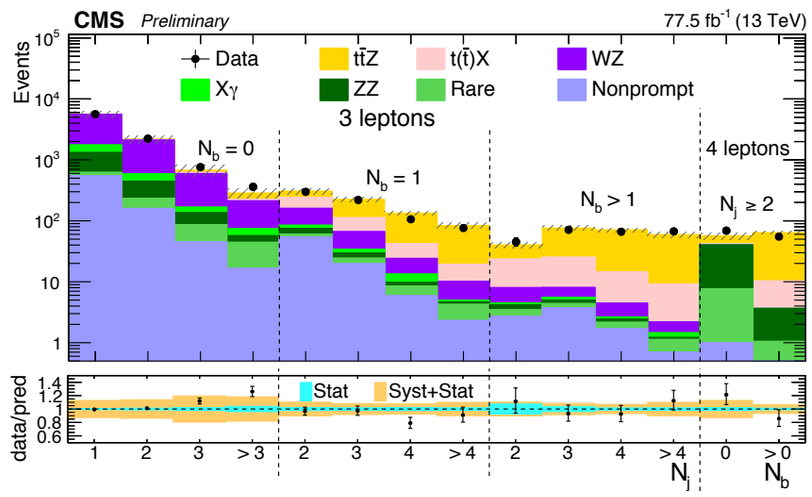


- tqZ CMS arXiv:1812.05900



- ttZ CMS-PAS-TOP-18-009

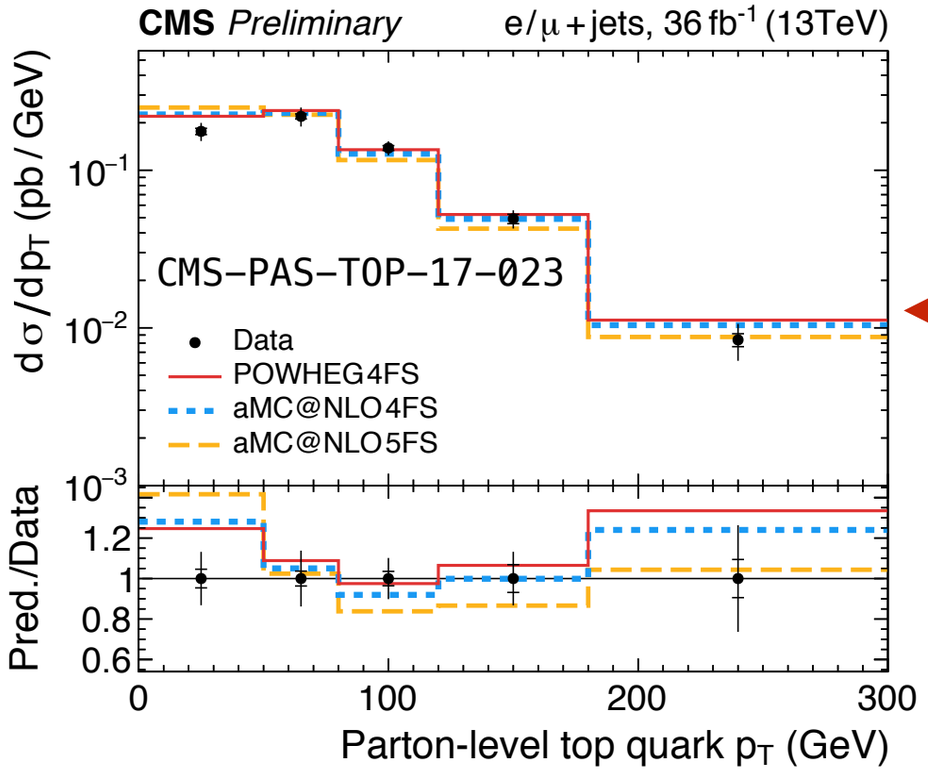
$$\sigma(t\bar{t}Z) = 1.00\ ^{+0.06}_{-0.05}\,(\mathrm{stat})\ ^{+0.07}_{-0.06}\,(\mathrm{syst})\ \mathrm{pb}$$

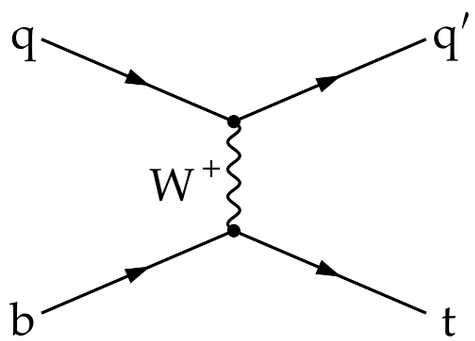


- single-top

limit V_{tb}

differential





ATLAS+CMS LHC*top*WG — Run1 LHC arXiv:1902.07158

$|f_{LV}V_{tb}| = \sqrt{\frac{\sigma_{meas.}}{\sigma_{theo.}}}$ from single-top-quark production

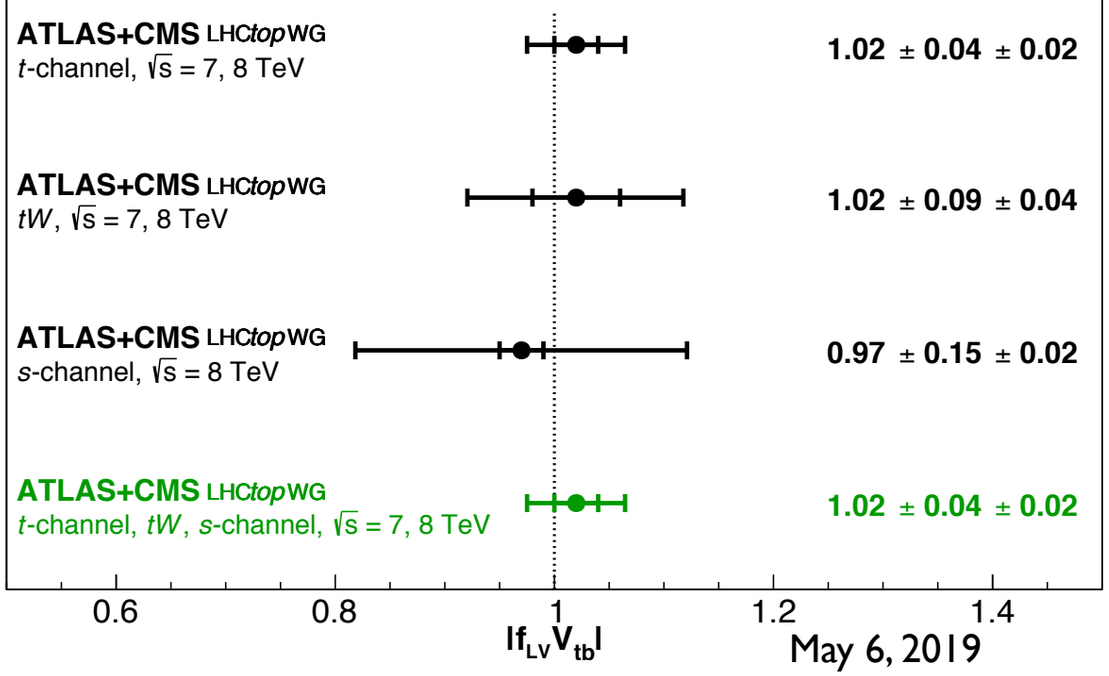
$\sigma_{theo.}$: NLO (t- and s-channel), NLO+NNLL (tW)

$\delta\sigma_{theo.}$: scale ⊕ PDF ⊕ α_s ⊕ m_t ⊕ E_{beam}

m_t = 172.5 GeV

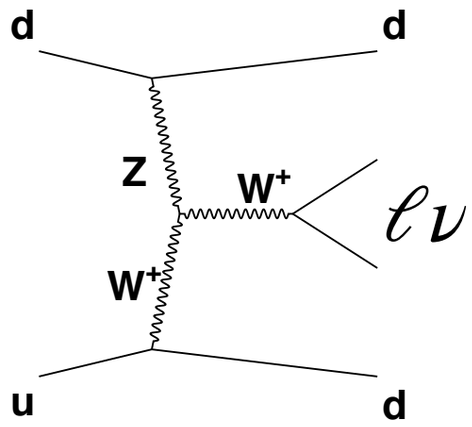
total theo.

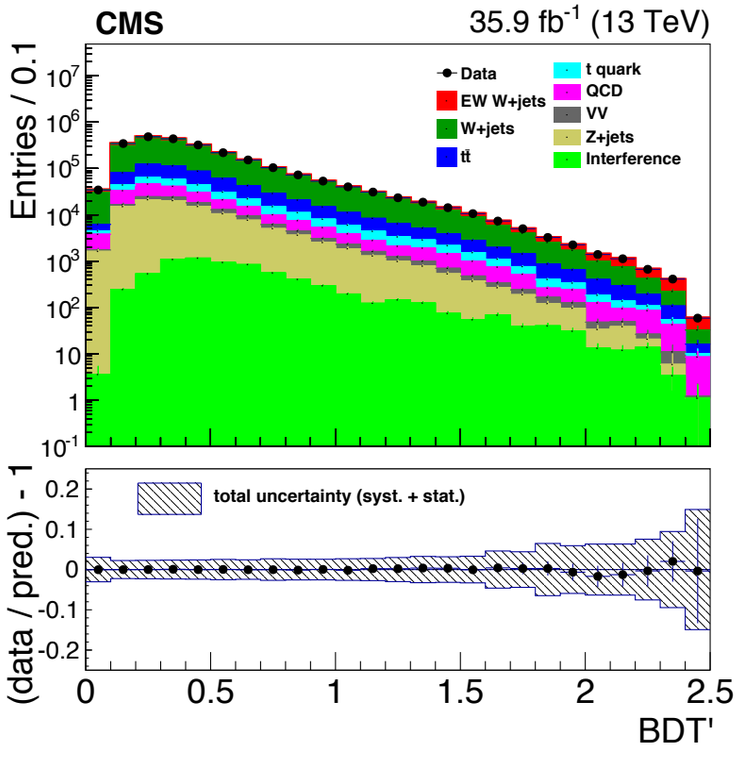
$|f_{LV}V_{tb}| \pm$ (meas.) $\pm$ (theo.)



W/Z: Triliniear Gauge Couplings and more…

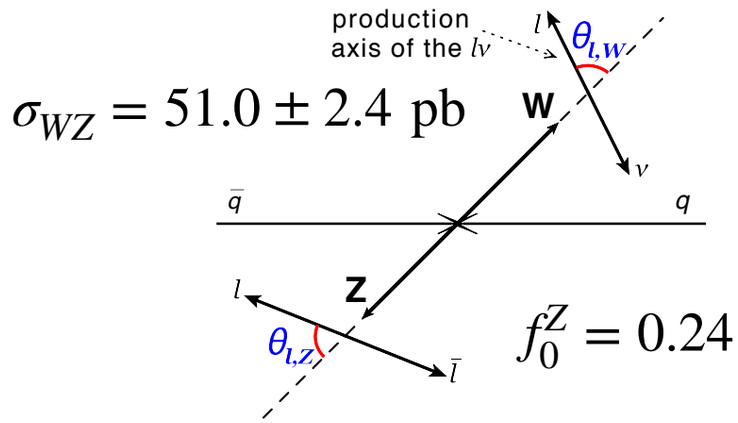
- CMS arXiv:1903.04040





$\sigma_{EW}(\ell\nu jj) = 6.23 \pm 0.12(\text{stat}) \pm 0.61(\text{syst})$ pb

- ATLAS arXiv:1902.05759

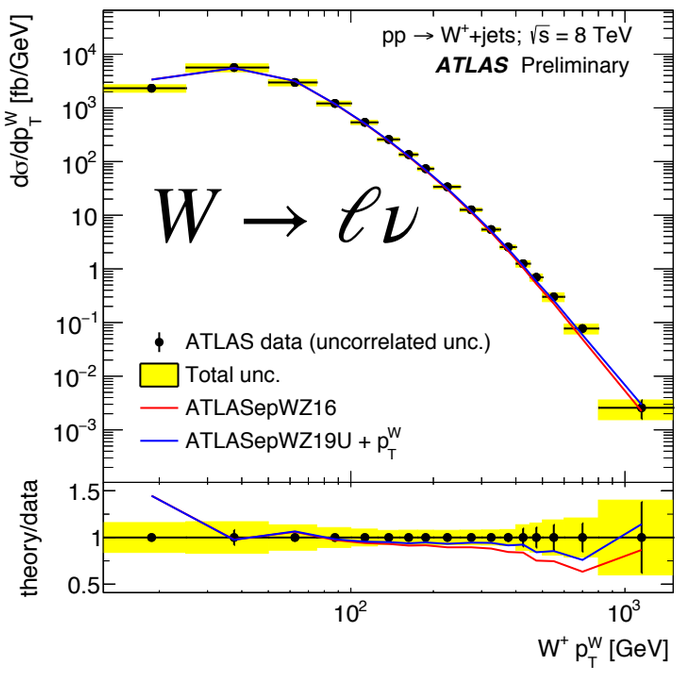


$\sigma_{WZ} = 51.0 \pm 2.4$ pb

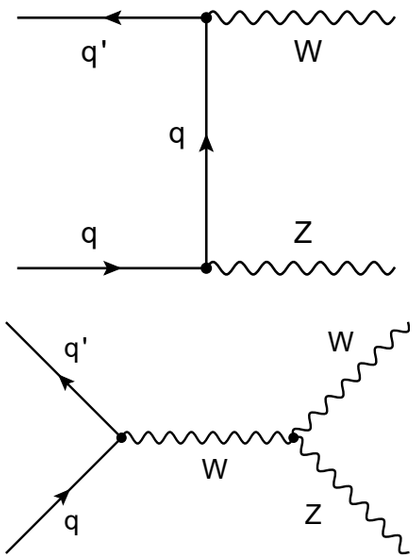
$f_0^Z = 0.24 \pm 0.04$

- ATL-PHYS-PUB-2019-016

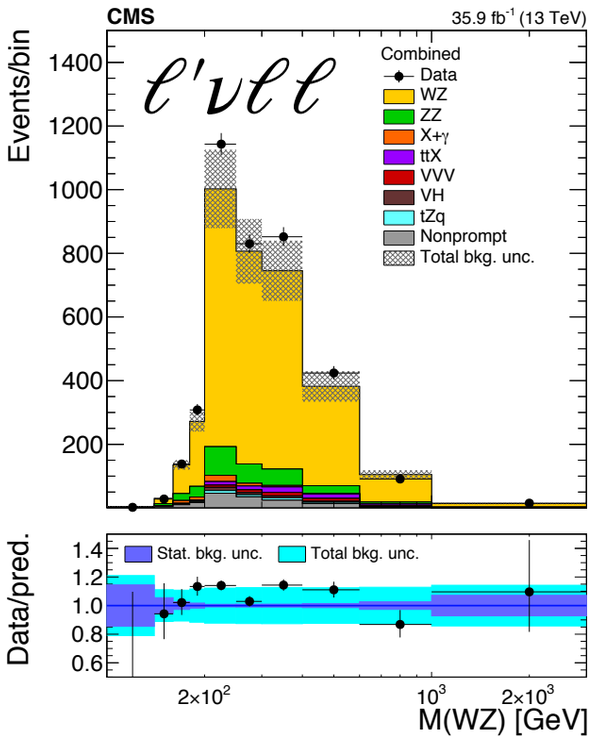
$W^{\pm}$ + jets ⇒ constrain PDF (with W, Z, and HERA)



- CMS arXiv:1901.03428

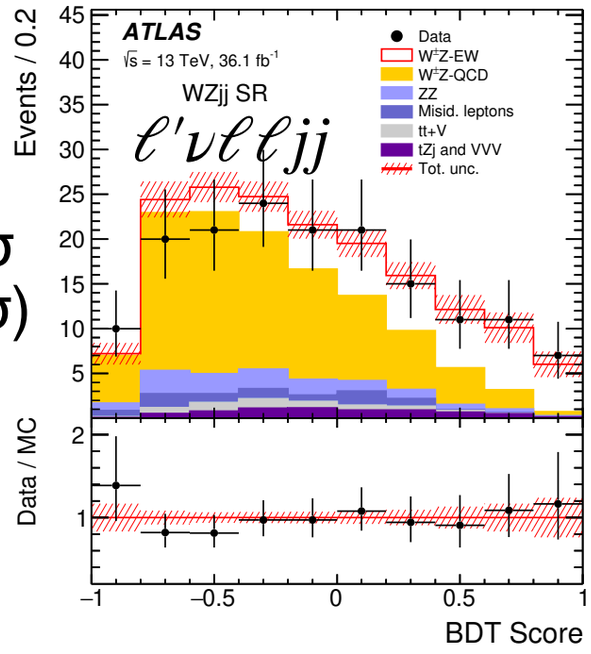


$\sigma_{WZ} = 48.09^{+2.98}_{-2.78}$ pb



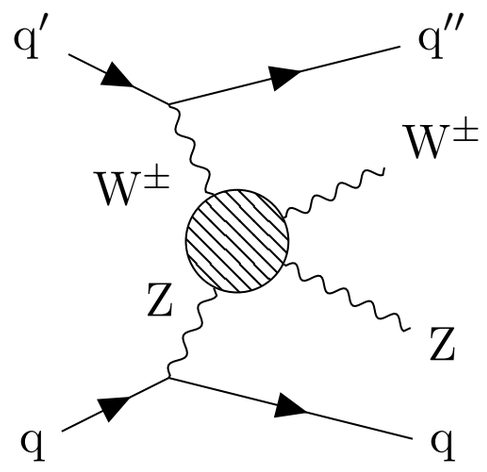
W/Z: Quartic Gauge Couplings and more…

- ATLAS arXiv:1812.09740



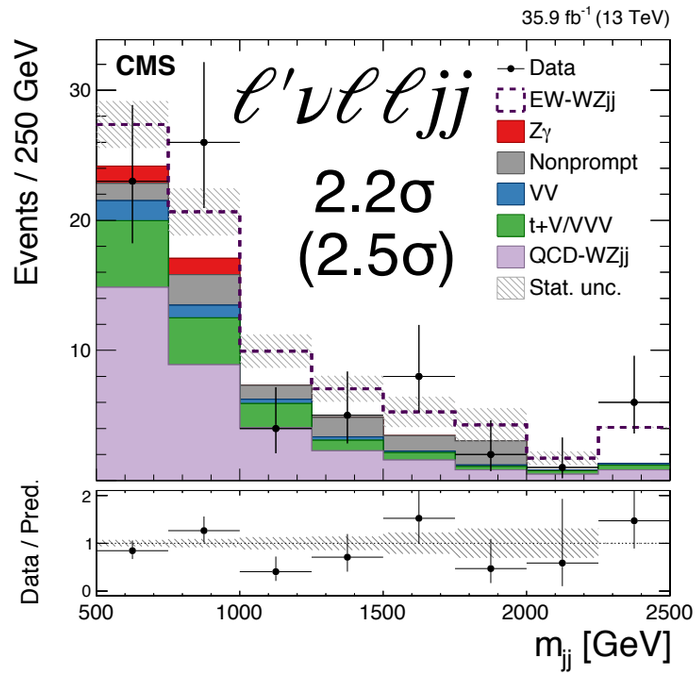
5.3σ
(3.2σ)

$$\sigma_{WZjj\text{-EW}} = 0.57\ ^{+0.14}_{-0.13}\,(\text{stat.})\ ^{+0.07}_{-0.06}\,(\text{syst.})\ \text{fb}$$



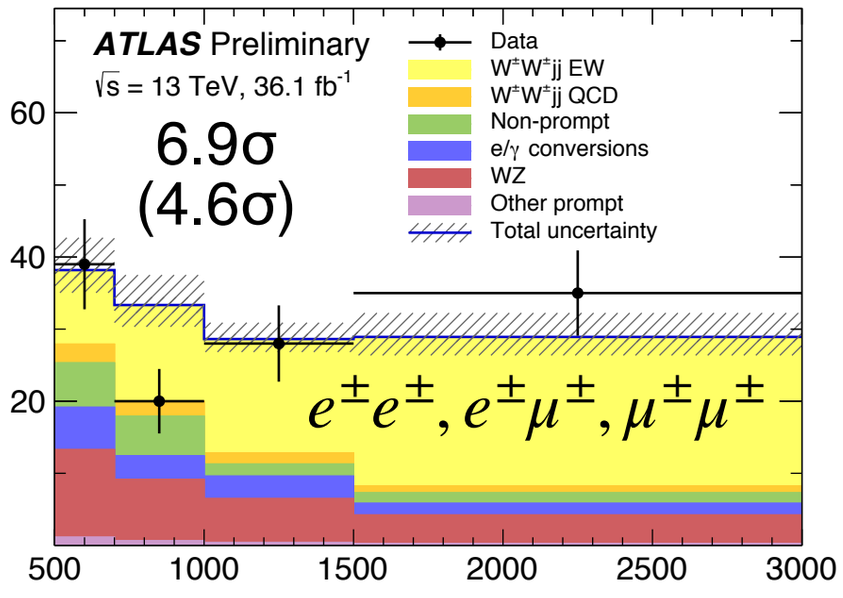
- CMS-PAS-SMP-18-006
  limits on aQGC
  in WW, WZ, ZZ +jj

- CMS arXiv:1901.04060



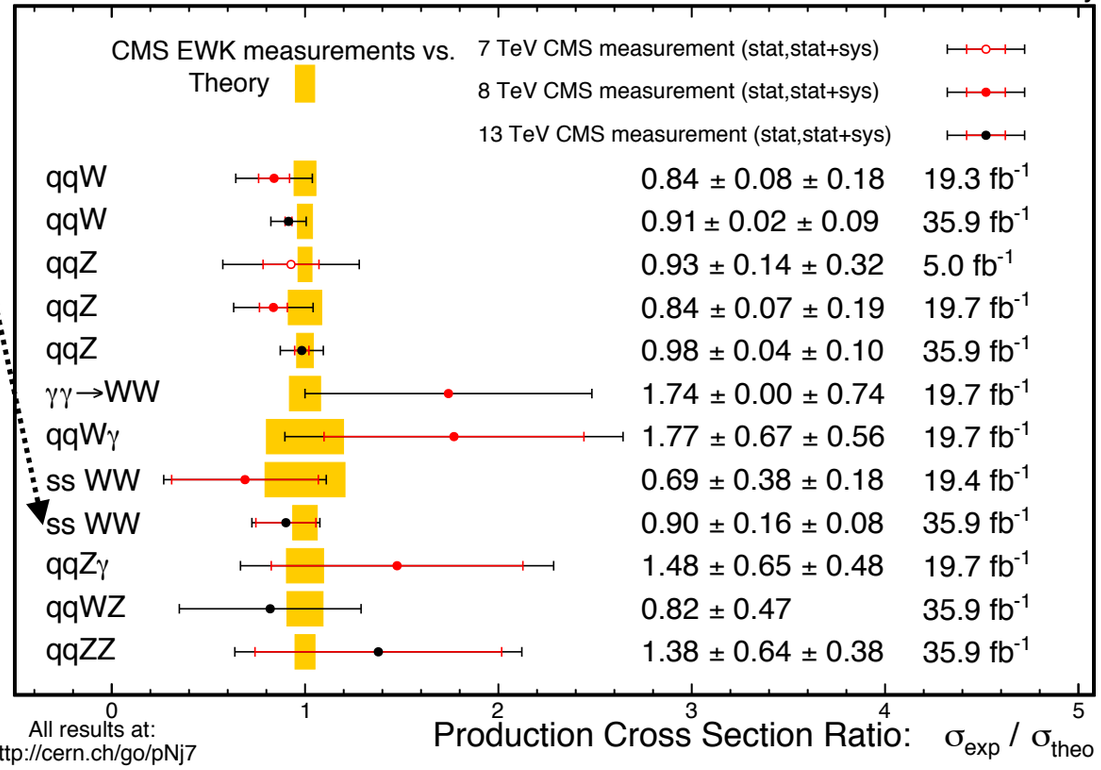
- ATLAS-CONF-2018-030 (earlier: CMS arXiv:1709.05822)

$W^{\pm}W^{\pm}jj$



$$\sigma^{\text{fid}} = 2.91^{+0.51}_{-0.47}\,(\text{stat.}) \pm 0.27\,(\text{sys.})\ \text{fb}$$

5.5σ
(5.7σ)

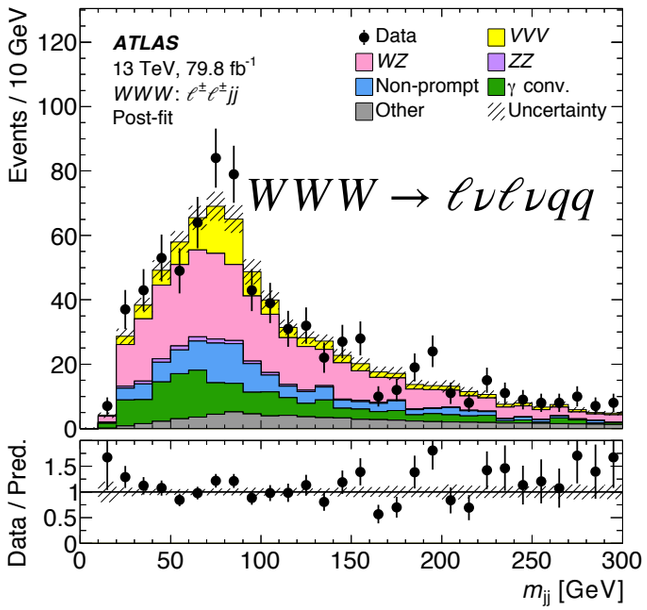


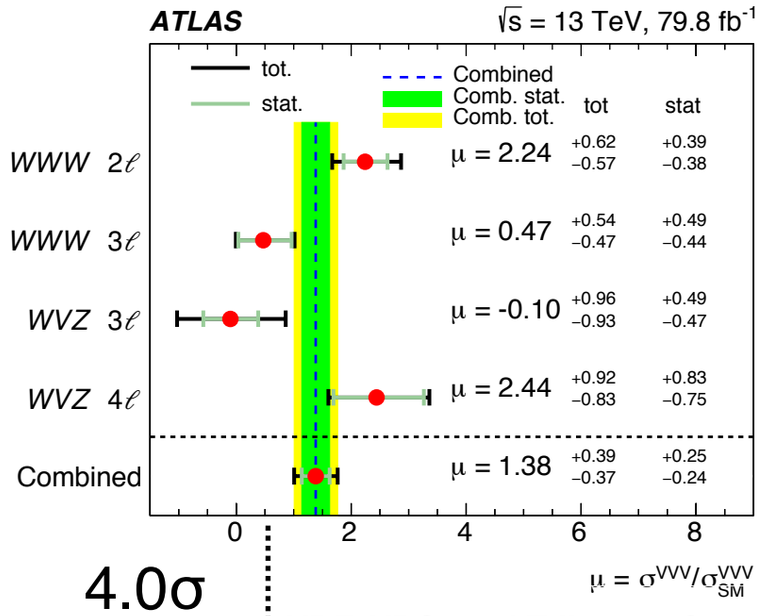
March 2019

CMS Preliminary

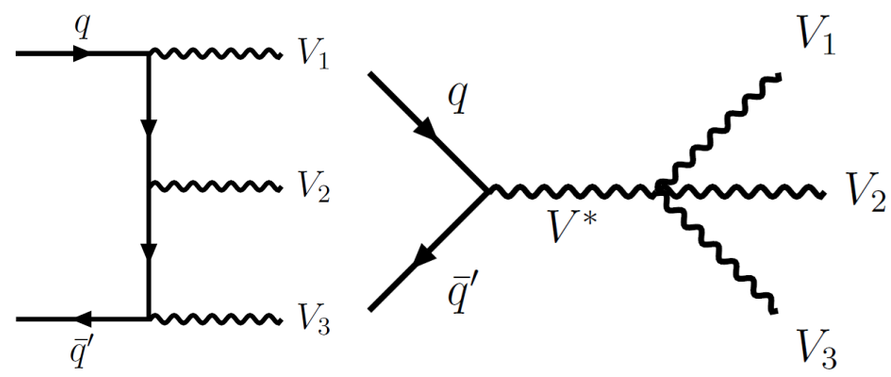
W/Z: Multiboson VVV

- ATLAS arXiv:1903.10415



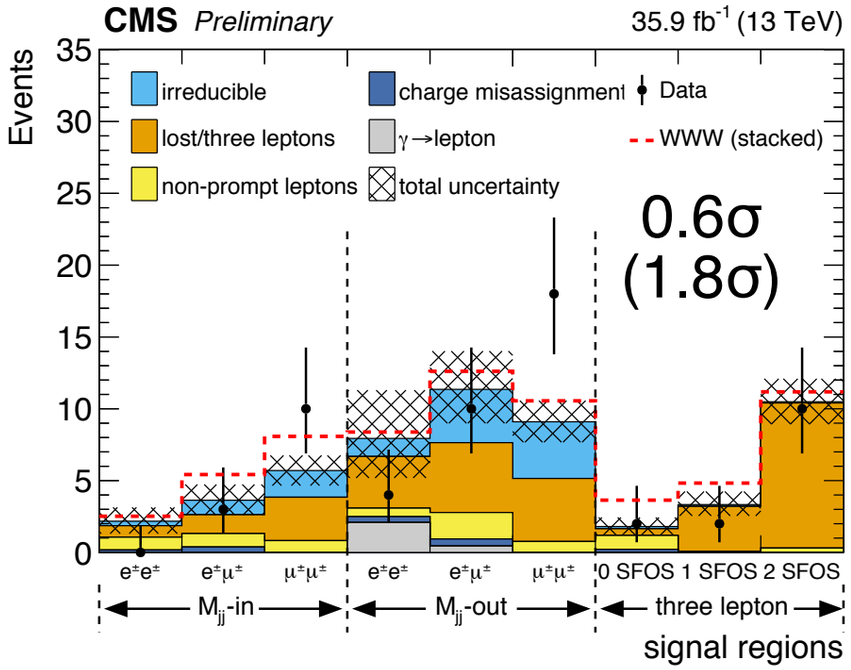


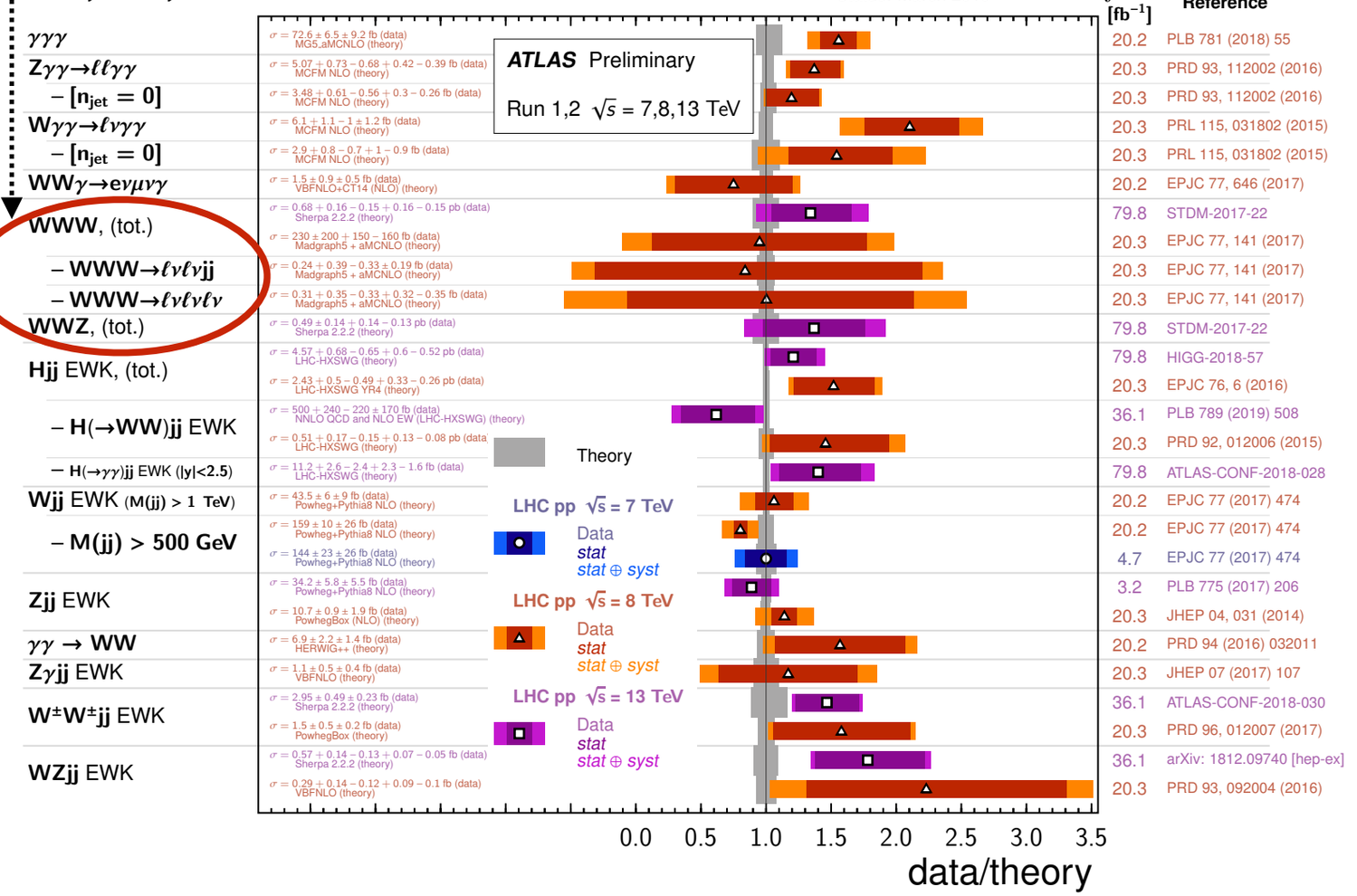
4.0σ
(3.1σ)



- CMS-PAS-SMP-17-013

$W^{\pm}W^{\pm}W^{\mp} \to \ell^{\pm}\nu\ell^{\pm}\nu qq$ and $\ell\nu\ell\nu\ell\nu$





H: rare/exotic processes

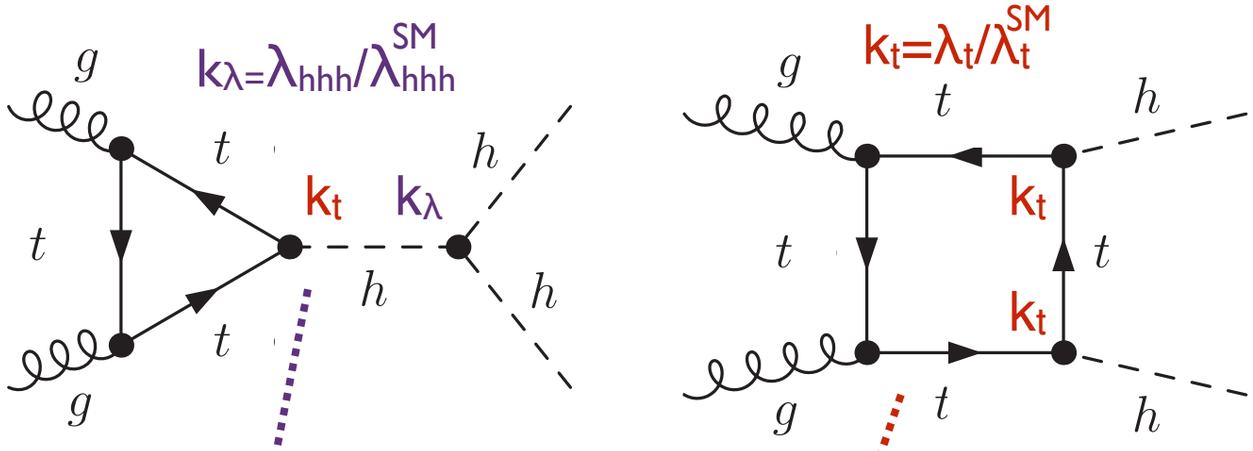
- H(125) → Zγ, μμ, μτ, J/ψJ/ψ, YY, cc, a_1a_1, …
- extended H sector…

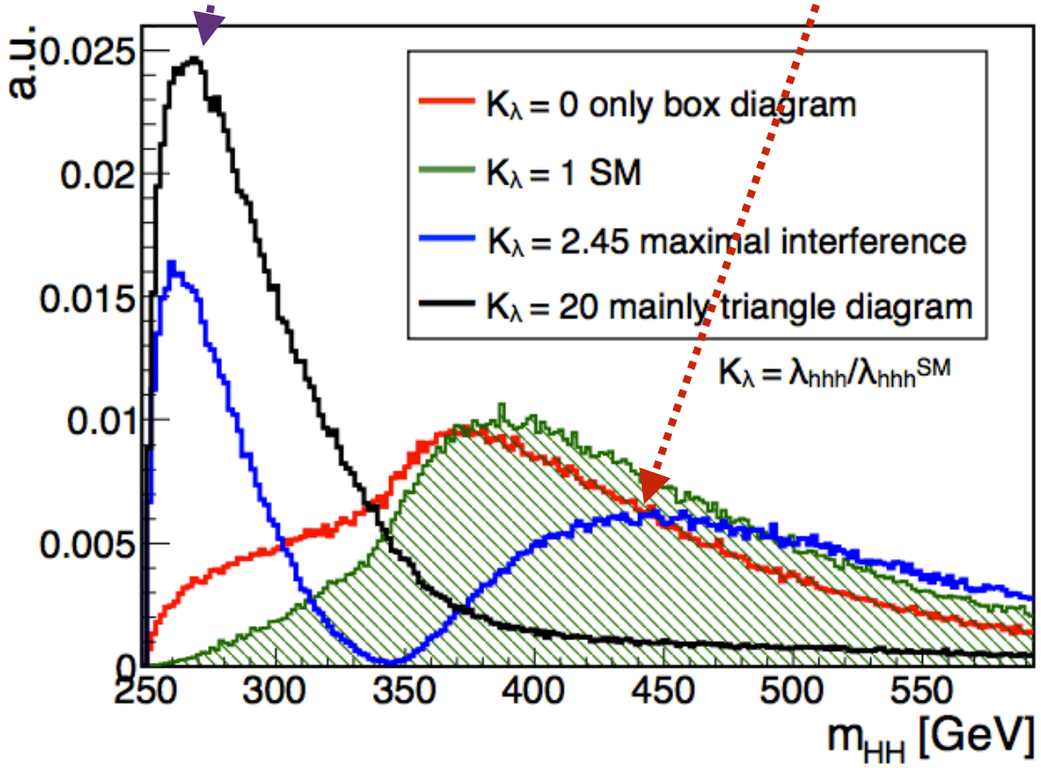
see parallel sessions and next talk for more!

Higgs self-coupling (φ^4)

HL-HLC and indirect (see backup)

- H(125)H(125) — rare process:



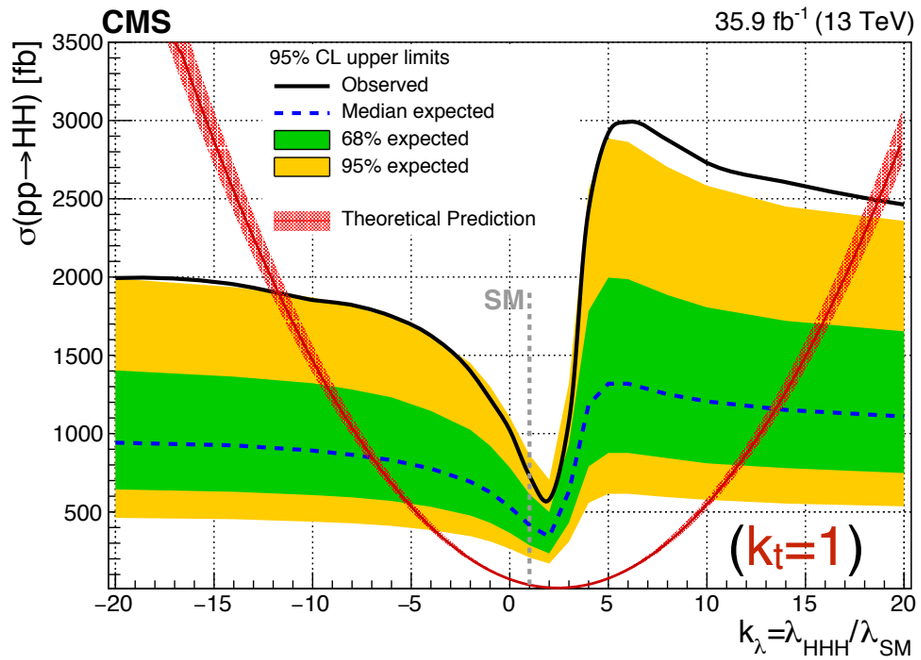


- CMS arXiv:1811.09689

HH→bb+(bb/γγ/ττ/WW/ZZ)

$\sigma/\sigma_{SM} < 22.2$ (exp. <12.8)

$-11.8 < \kappa_\lambda < 18.8$



- ATLAS-CONF-2018-043

HH→bb+(bb/γγ/ττ)

$\sigma/\sigma_{SM} < 6.7$ (exp. <10.4)

$-5.0 < \kappa_\lambda < 12.1$

H, W/Z, top: pre-view of the parallel sessions

- 16 talks at the parallel sessions:

Higgs boson

- BSM Higgs results from ATLAS
- Searches for Higgs boson exotic decays at CMS
- Searches for rare decays of the Higgs boson at CMS
- ATLAS Searches for VH/HH Resonances
- Combined Higgs boson measurements at the ATLAS experiment
- Measurement of differential and production mode cross sections and the Higgs mass in Higgs boson in decays to bosons using the ATLAS detector
- Measurements and searches of Higgs boson decays to two fermions and of Higgs boson production in association with a ttbar pair at ATLAS

W/Z bosons

- Electroweak physics with multibosons at CMS
- Measurements of multiboson production using the ATLAS detector
- Electroweak physics with single and diboson final states at CMS
- Observation and measurements of vector-boson scattering with ATLAS
- Precision electroweak measurements with ATLAS
- Probing perturbative QCD using electroweak bosons at ATLAS

Top quark

- Measurements of ttbar pairs produced in association with electroweak gauge bosons using the ATLAS detector
- Top quark pair property measurements using the ATLAS detector at the LHC
- Top-quark pair production cross-section measurements with the ATLAS detector

Higgs boson LHC links:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIG

W/Z boson LHC links:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP

Top quark LHC links:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP

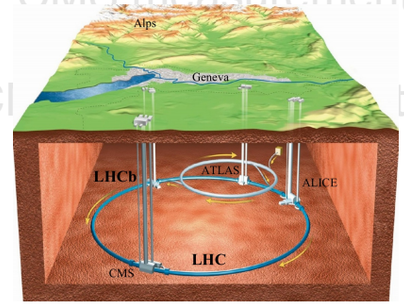
Summary (H,W/Z, top: view from the speaker)

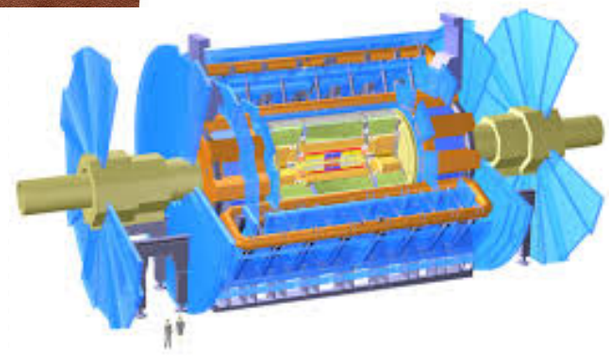
- LHC is the H,W/Z, top factory
  even more so at HL-LHC

- ATLAS and CMS
  progress beyond just $\mathscr{L}$umi

- Exploring full Run-2 dataset
  established all major processes
  closing on / excluding rare modes
  sensitive to virtual effects
  determine fundamental parameters

- Ultimately trying to establish the big picture…



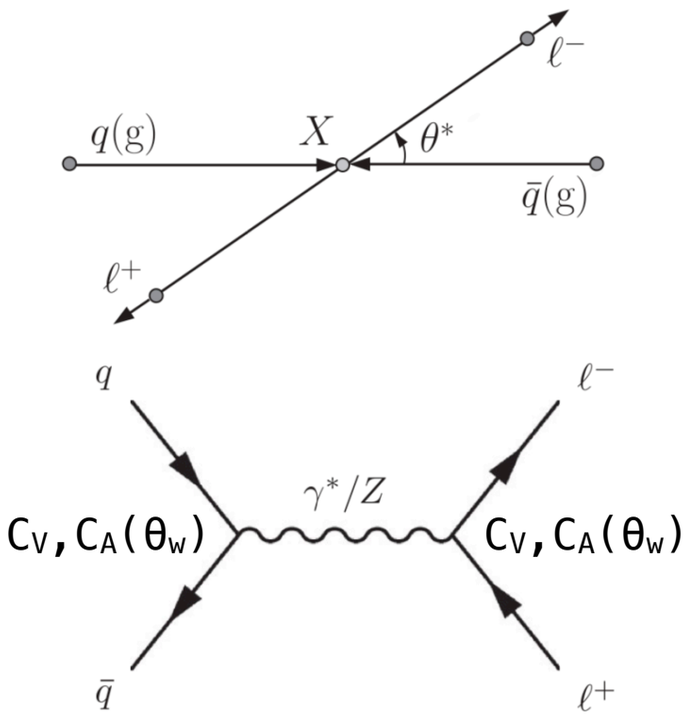


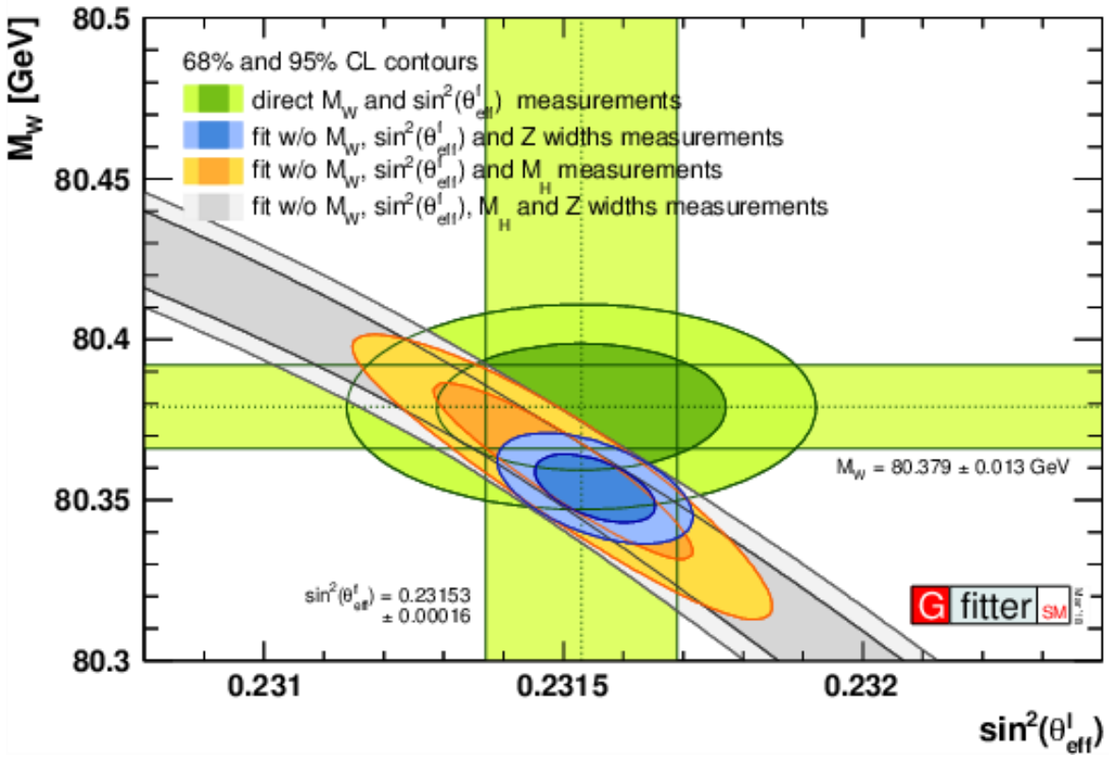
H, W, Z, γ	Electro-Weak	top

…
? $+|D_\mu\varphi|^2$
$+\psi_i y_{ij} \psi_j \varphi$ +h.c.
$-V(\varphi)$?
$..\varphi_1..\varphi_2..$

H, W/Z, top: some HL-LHC projections

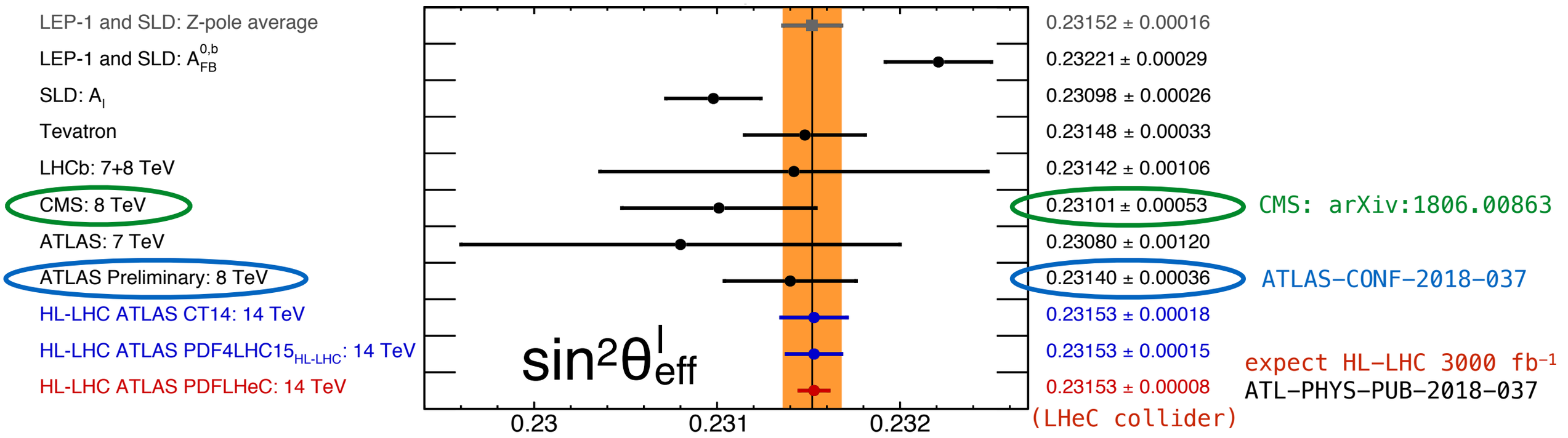
Z/γ*: spin correlations (weak mixing angle θ_W)





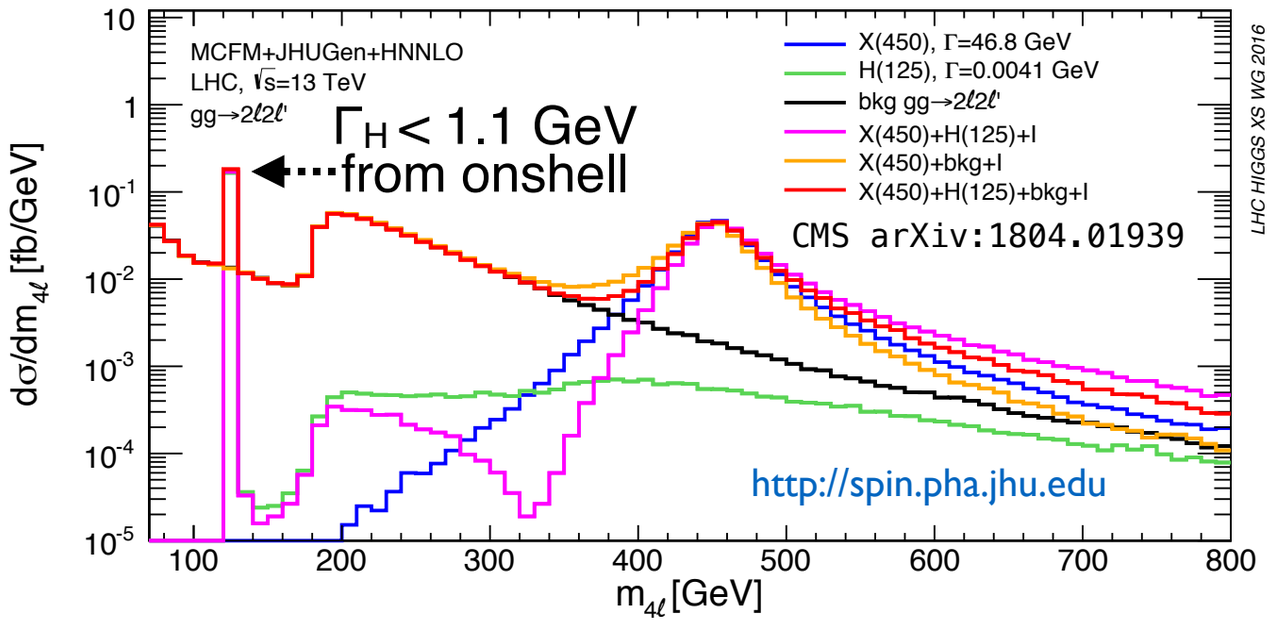
CMS: 0.23101 ± 0.00036 (stat.) ± 0.00031 (PDF) ± 0.00018 (syst.) ± 0.00016 (theo.)

ATLAS: 0.23140 ± 0.00021 (stat.) ± 0.00024 (PDF) ± 0.00016 (syst.)



H: the width (offshell H*)

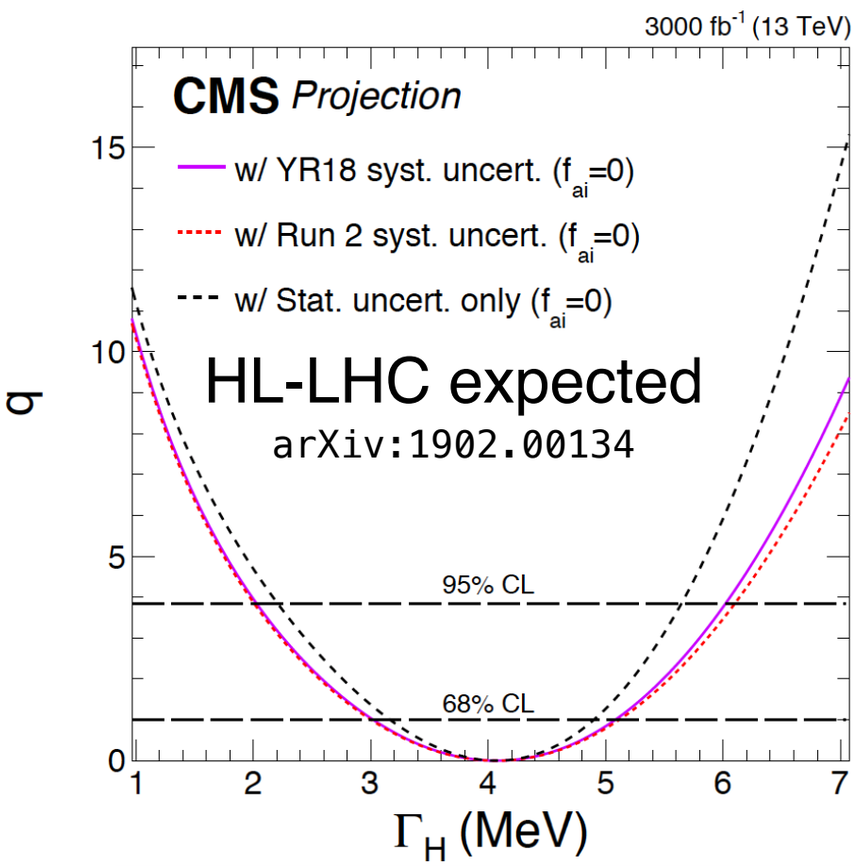
H→ZZ* (onshell) vs. H*→ZZ (offshell)



$$\frac{\mathrm{d}\,\sigma_{gg\to H\to ZZ}}{\mathrm{d}\,m^2_{ZZ}} \sim \frac{g^2_{\mathrm{ggH}} g^2_{\mathrm{HZZ}}}{(m^2_{ZZ}-m^2_H)^2 + m^2_H \Gamma_H{}^2}$$

~ 10% in SM, but:
offshell "enhancement"

(1) larger width Γ_H
(2) new resonance X
(3) anomalous couplings



arXiv:1902.00134

ATLAS+CMS

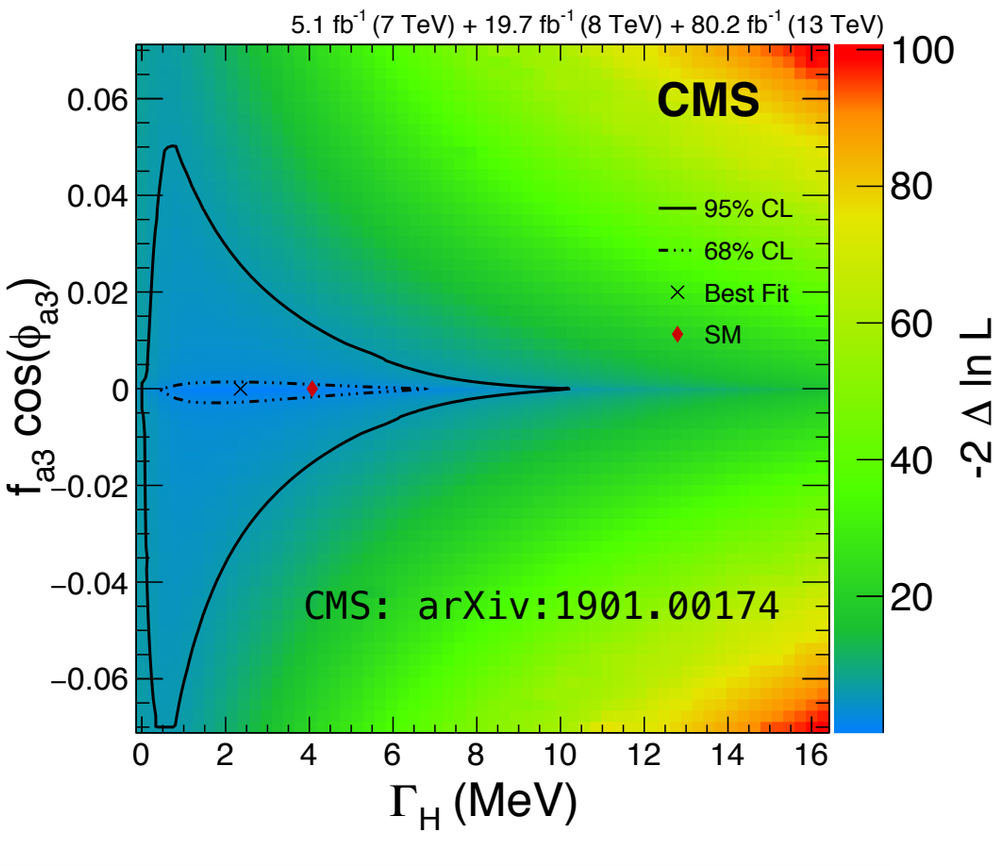
HL-LHC expect

3000 fb^{-1}

$\Gamma_H = 4.1 \pm 0.8$ MeV

expected uncertainty

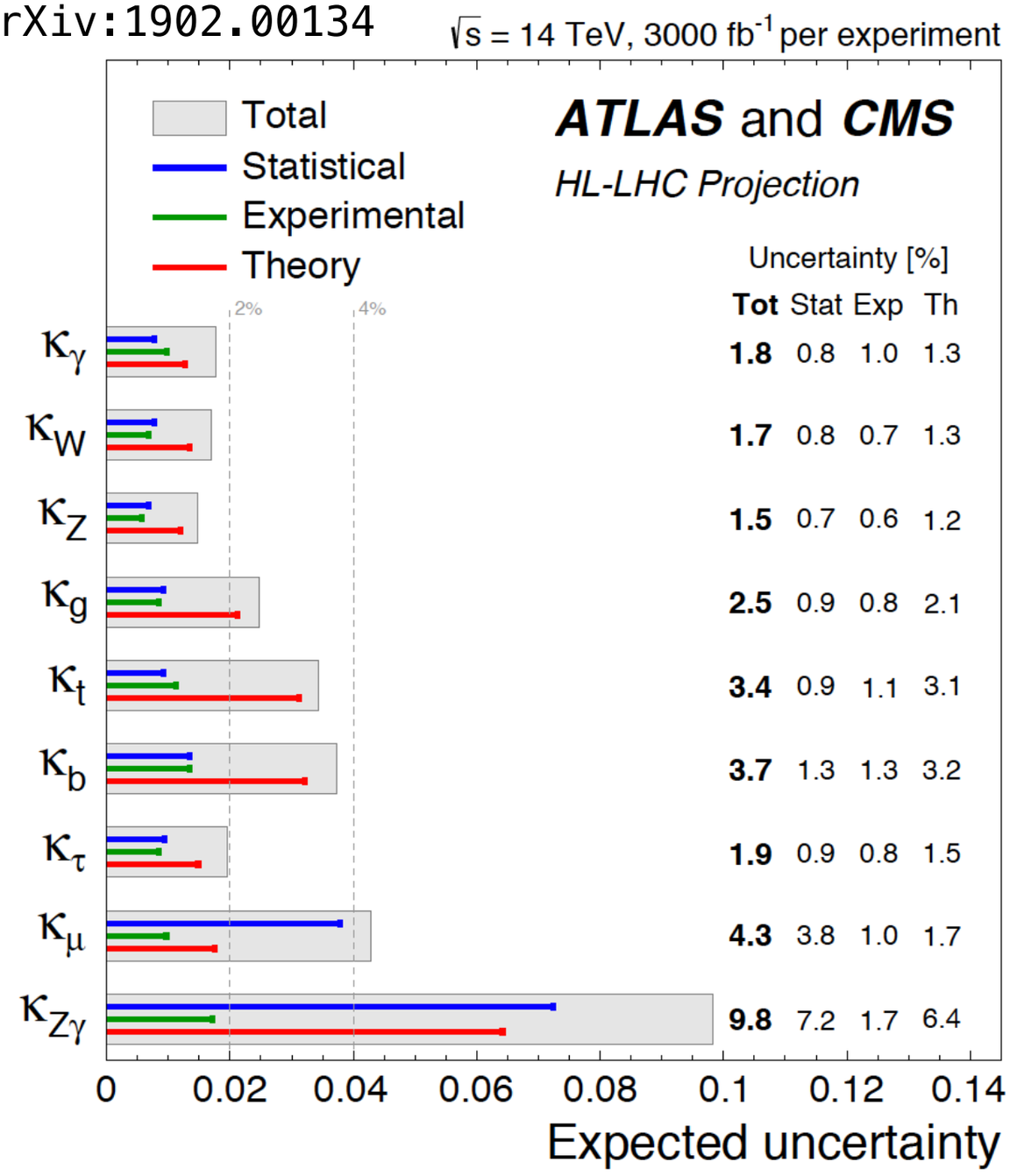
expected in SM

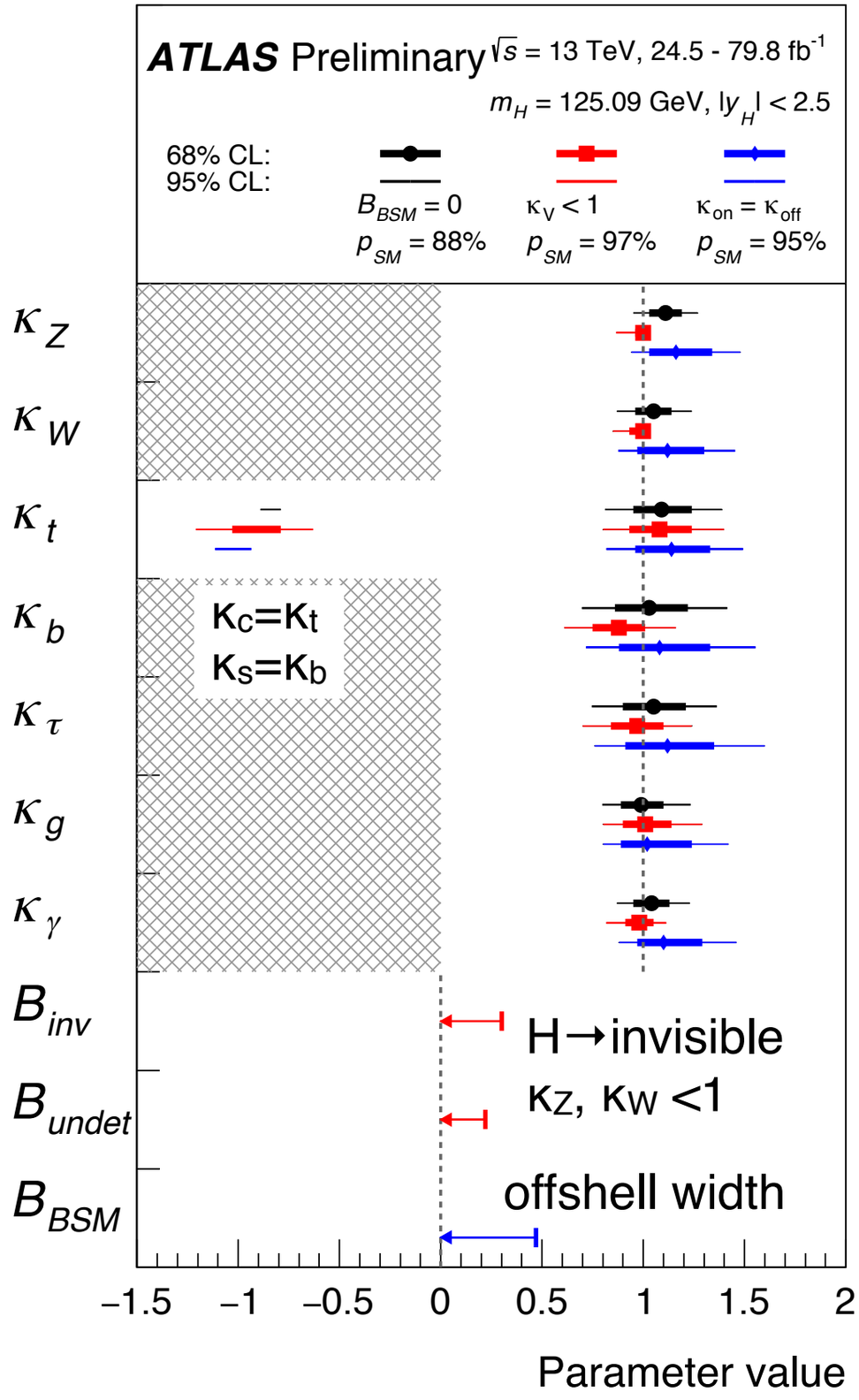


H: couplings

- HL-LHC expect 3000 fb^{-1}
  —reaching 2-4% precision

arXiv:1902.00134

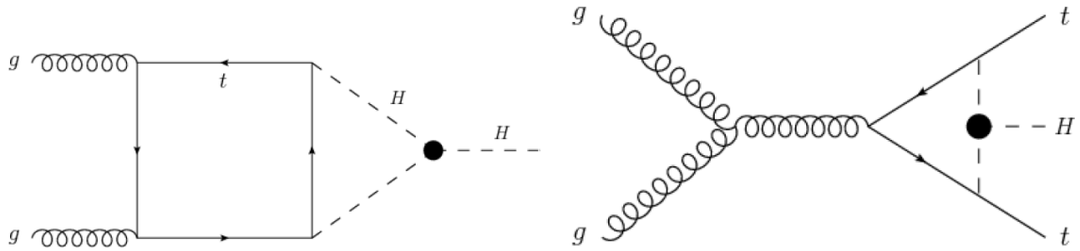




H: self-coupling

- H self-coupling:

—indirect constraints



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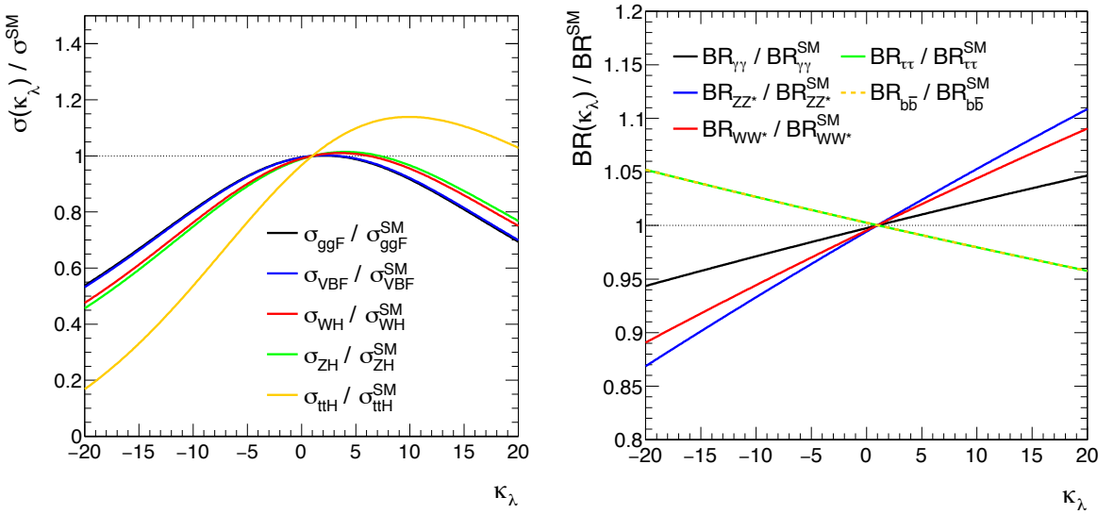
$-3.2 < \kappa_\lambda < 11.9$ (exp. $-6.2 < \kappa_\lambda < 14.4$)



Analysis	Integrated luminosity (fb^{-1})
$H \to \gamma\gamma$ (including $t\bar{t}H, H \to \gamma\gamma$)	79.8
$H \to ZZ^* \to 4\ell$ (including $t\bar{t}H, H \to ZZ^* \to 4\ell$)	79.8
$H \to WW^* \to e\nu\mu\nu$	36.1
$H \to \tau\tau$	36.1
$VH, H \to b\bar{b}$	79.8
$t\bar{t}H, H \to b\bar{b}$ and $t\bar{t}H$ multilepton	36.1

STXS

—direct constraints

best expected now $-5.8 < \kappa_\lambda < 12.0$

target of HL-LHC and HE-LHC:

(14 TeV, 3/ab) (27 TeV, 15/ab)

arXiv:1902.00134