Higgs Measurements at LHC

Ye Chen

on behalf of  collaborations

24/12/2017, Nanjing

Outline

1. Overview: SM like Higgs Boson Measurements at LHC
2. Highlight of 2017: Direct Observation of SM like Higgs $\rightarrow \tau\tau$
3. Highlight of 2017: Evidence of SM like Higgs $\rightarrow b\bar{b}$
4. Highlight of 2017: PDG μ update, SM like Higgs $\rightarrow \mu\mu$
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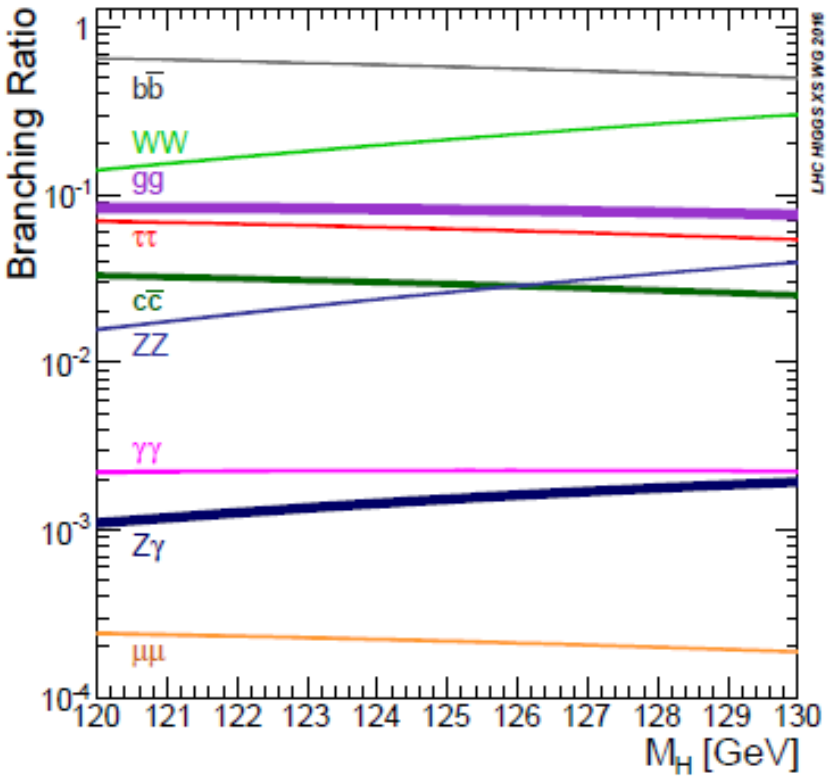
6. Summary and Outlook

H(125) of Today



Chin.Phys.C40,100001(2016)

H^0

$J = 0$

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

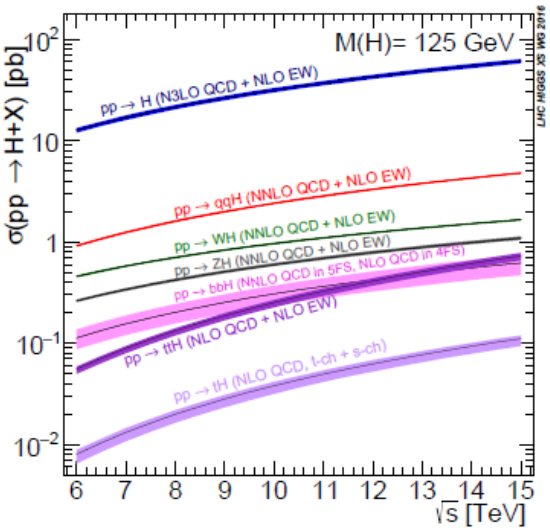
H^0 Signal Strengths in Different Channels

See Listings for the latest unpublished results.

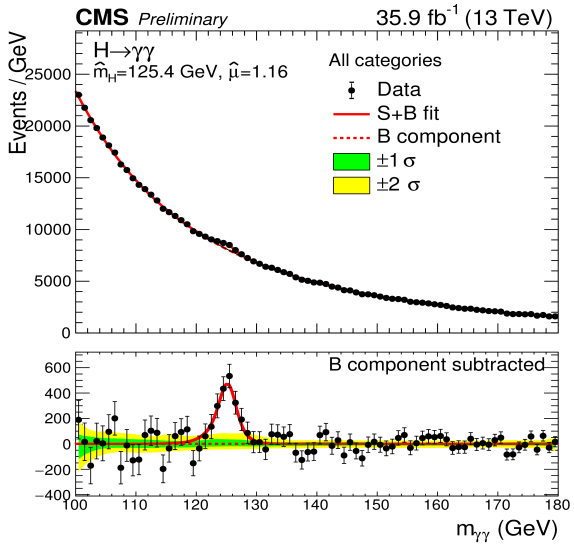
Combined Final States $= 1.10 \pm 0.11$
$WW^* = 1.08^{+0.18}_{-0.16}$
$ZZ^* = 1.29^{+0.26}_{-0.23}$
$\gamma\gamma = 1.16 \pm 0.18$
$b\bar{b} = 0.82 \pm 0.30 \quad (S = 1.1)$
$\mu^+\mu^- = 0.1 \pm 2.5$
$\tau^+\tau^- = 1.12 \pm 0.23$
$Z\gamma < 9.5$, CL = 95%
$t\bar{t}H^0$ Production $= 2.3^{+0.7}_{-0.6}$

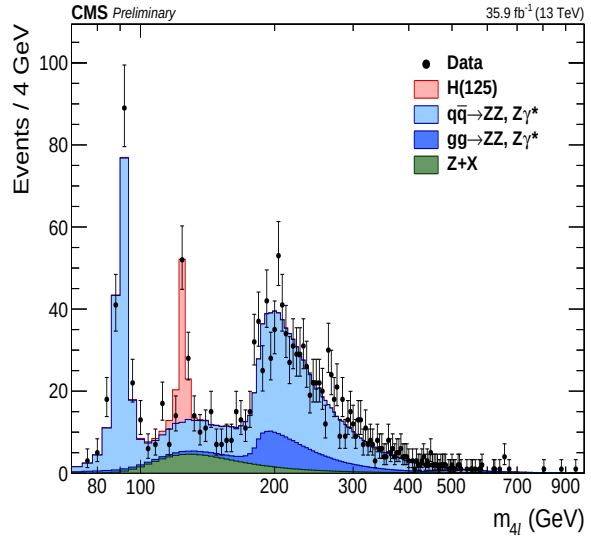
Compatible with Standard Model ...

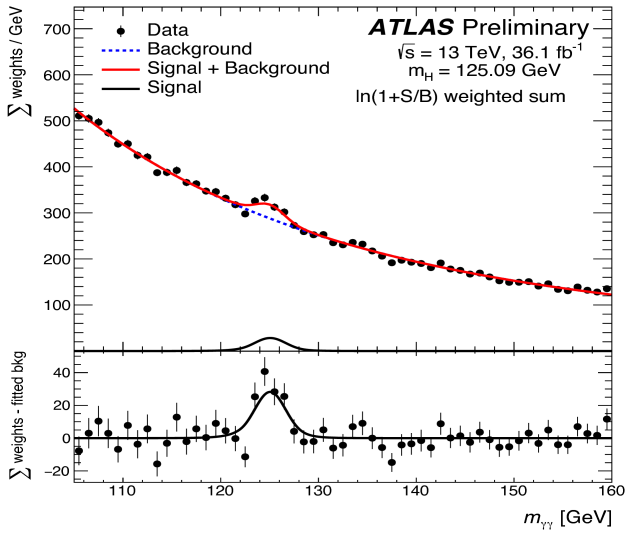
Reloading H(125) with 13 TeV

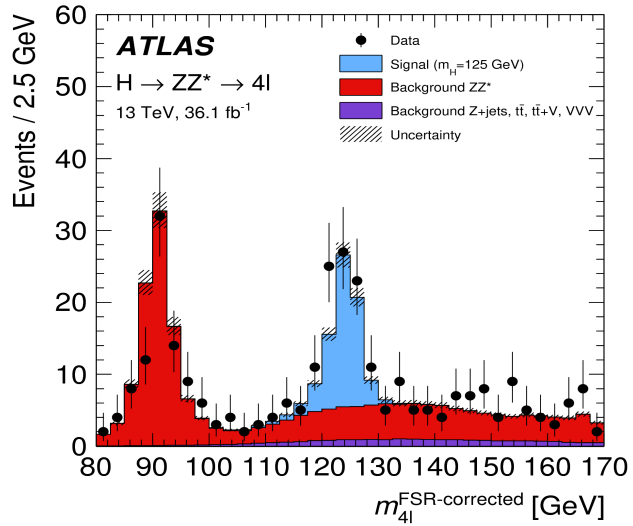


- CMS-PAS-HIG-16-040/041.
- ATLAS-CONF-2017-047/046/045.

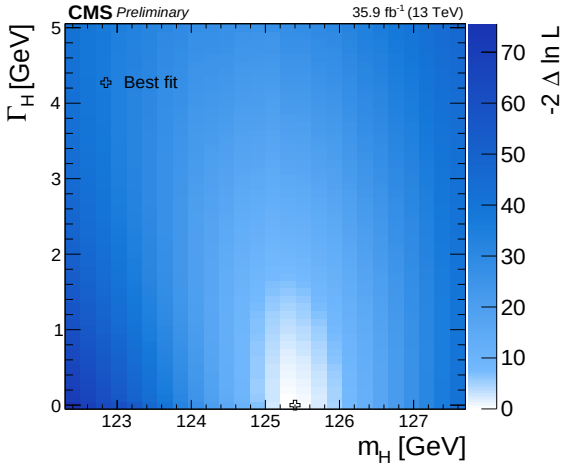


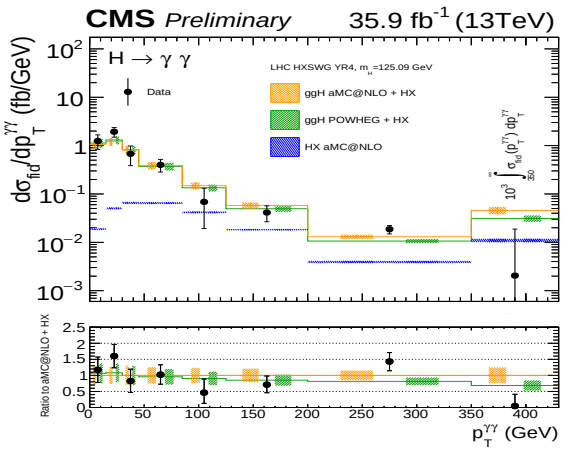


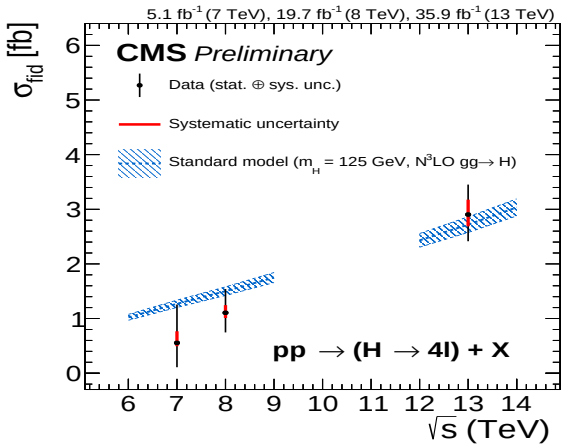


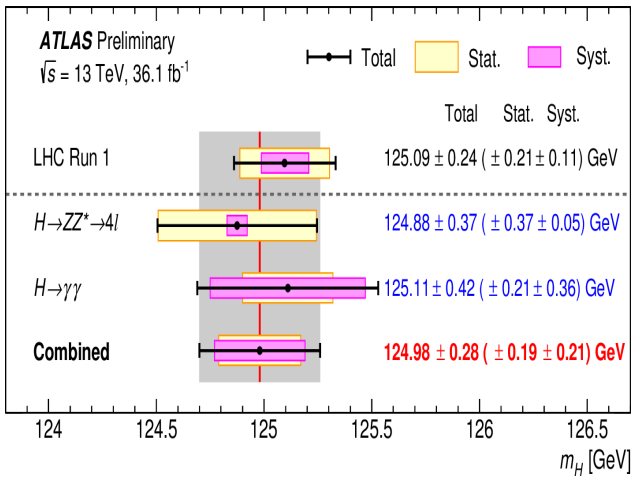


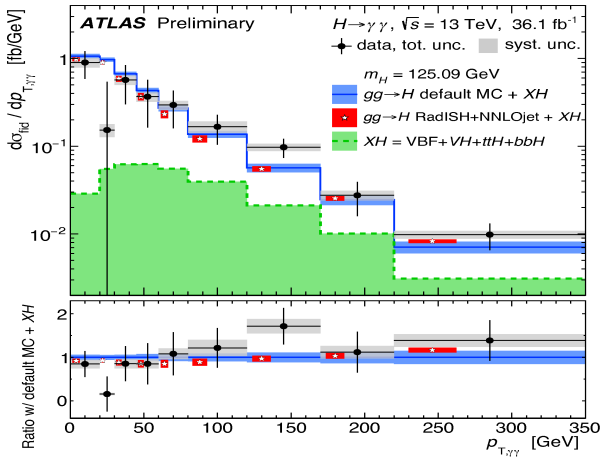
An Era of New Precision ...

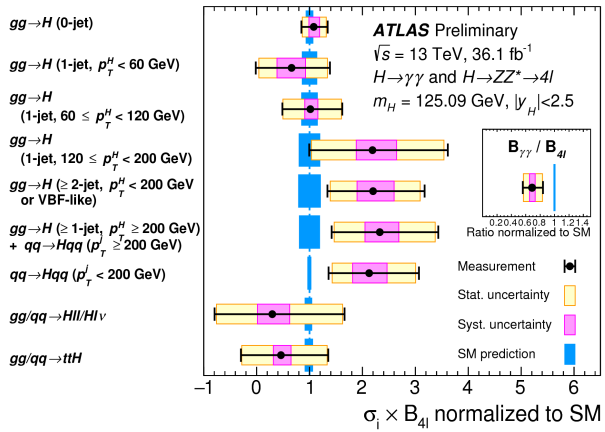












Mass, fiducial and simplified templete cross sections.
Larger dataset allows us to make more differential measurements ...

SM like Higgs Parallel Talks

- Higgs property measurement in di-photon final states.
  Speaker: Prof. Yanping Huang (IHEP)
- Measurements of Higgs boson cross sections and couplings in the $\gamma\gamma$ decay channel.
  Speaker: Muhammad Aamir SHAHZAD (IHEP)
- Higgs mass measurement in $H \rightarrow ZZ \rightarrow 4l$ channel.
  Speaker: Tahir JAVAID (IHEP)
- First Evidence of Higgs Decay into bb with the ATLAS Detector.
  Speaker: Ma Yanhui (SDU)
- Searches for ttH production with $\sqrt{s}$ = 13 TeV pp collisions at the CMS experiment.
  Speaker: Na PENG (IHEP)
- Searching for Higgs boson production in association with a top quark pair in multilepton final states.
  Speaker: Prof. Rustem Ospanov (USTC)
- Probing Higgs Width and Top Quark Yukawa Coupling from ttH and tttt Productions.
  Speaker: Liu Yandong (PKU)
- Measurement of the SM Higgs boson couplings using mumu decay channels with the ATLAS detector.
  Speaker: Prof. Haifeng Li (SDU)
- Combined Higgs Boson Coupling Measurements with 2015 and 2016 data at $\sqrt{13}$ TeV.
  Speaker: Ran Kunlin (IHEP)

see the details of your favorite measurements in the parallels.

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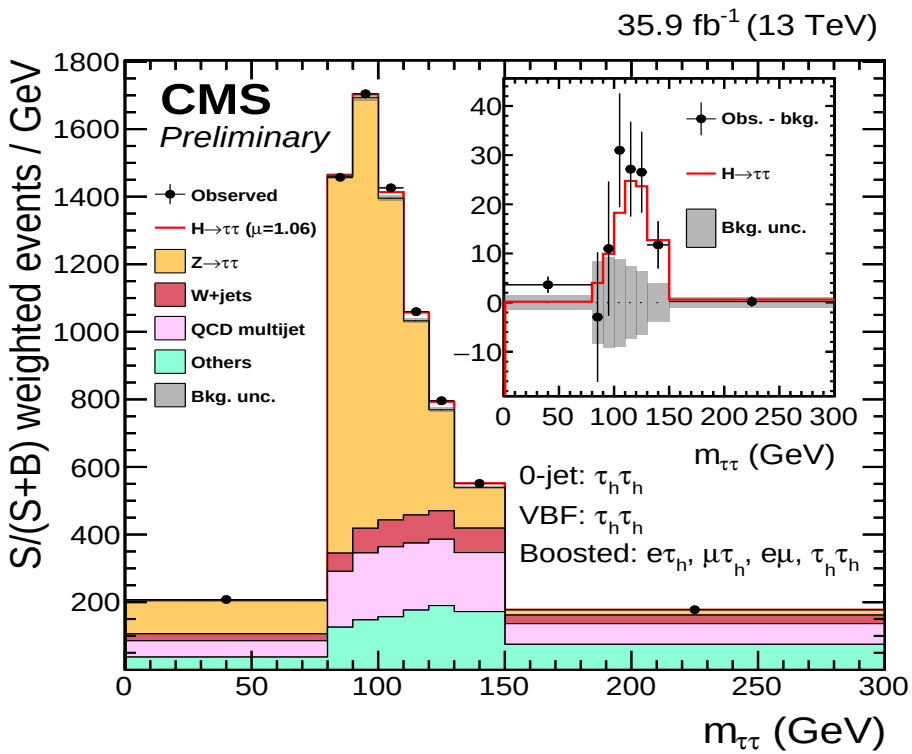
Direct Observation of Higgs $\to \tau\tau$

Submitted to PLB

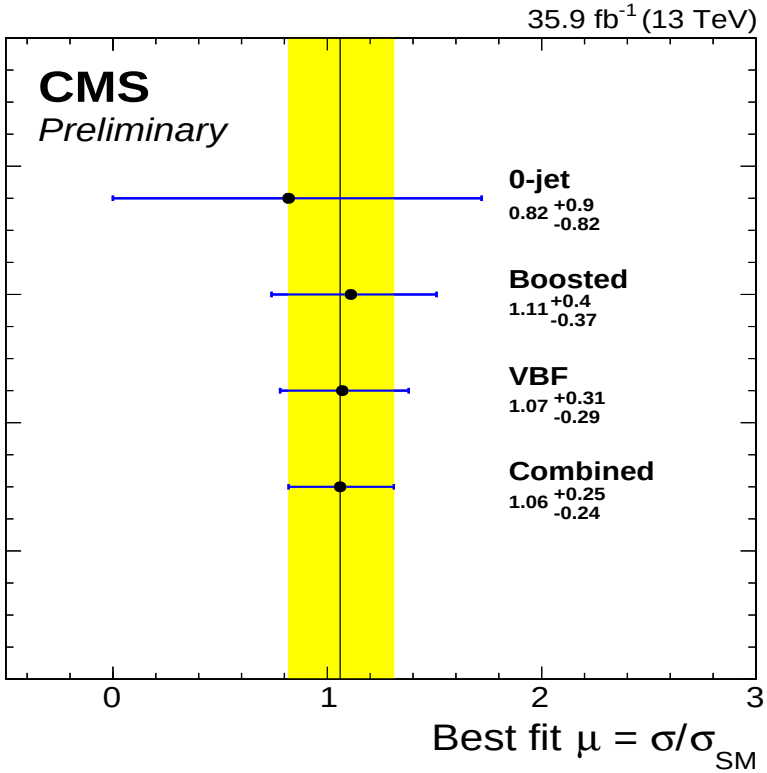


- Four decay modes, $\mu\tau_h$, eτ_h,$\tau_h\tau_h$ and $e\mu$
- Dedicated τ triggers have been implemented.
- Three event categories per final state.
  - 0 jet
  - VBF
  - Boosted
- Main background: $Z \to \tau\tau$ or ll, W+jet, QCD, $t\bar{t}$

...

Direct Observation of Higgs $\to \tau\tau$

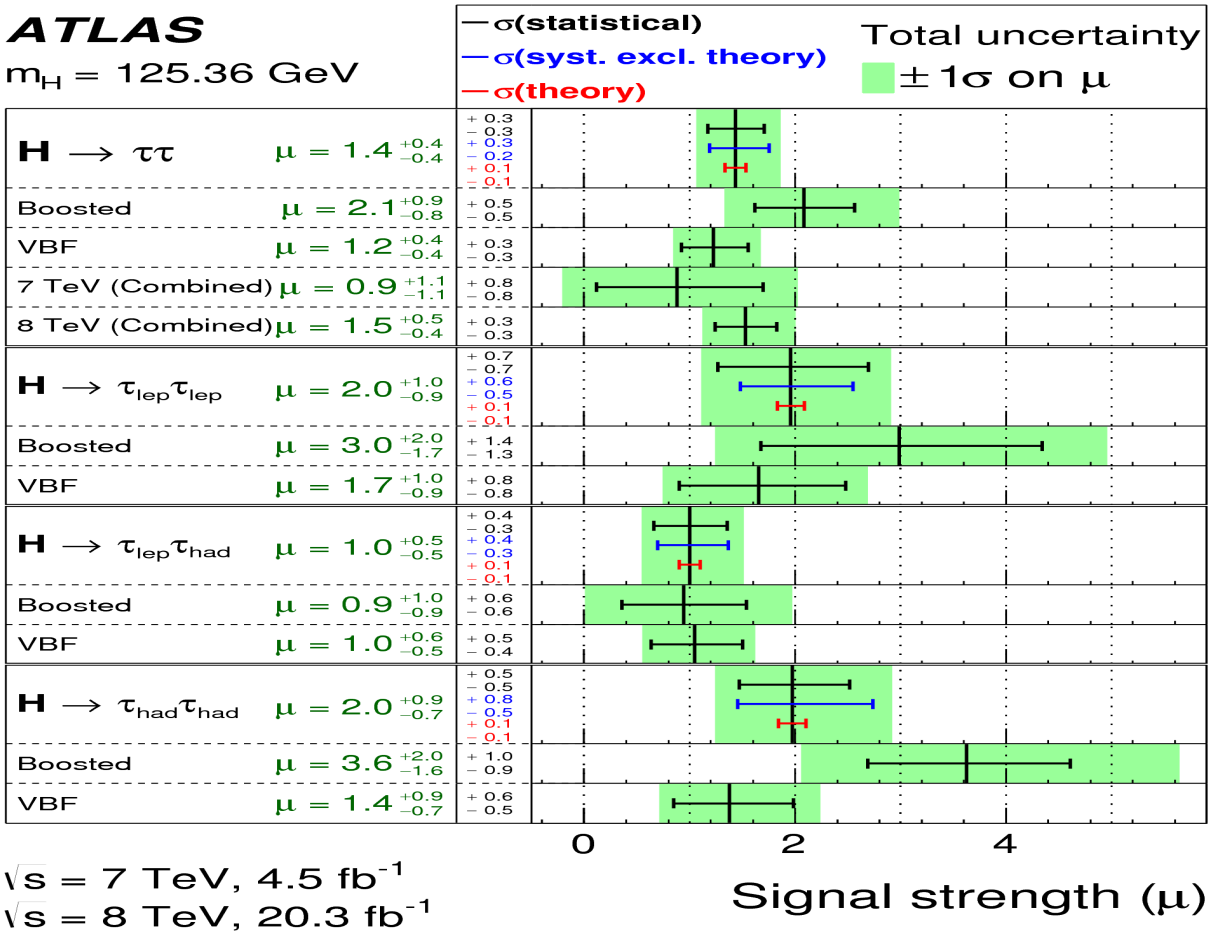
Submitted to PLB



- Combined Signal Strength $\mu = 1.06^{+0.25}_{-0.24}$.
- Significance of 35.9 fb^{-1}: 4.9σ.
- First direct observation of Fermionic decay of a single experiment: Run 2 + Run 1 5.9σ.

Reminder: ATLAS Run 1 Result

JHEP 04 (2015) 117



Significant: 4.5σ with 3.4σ expected

Updating with Run 2 is expected ...

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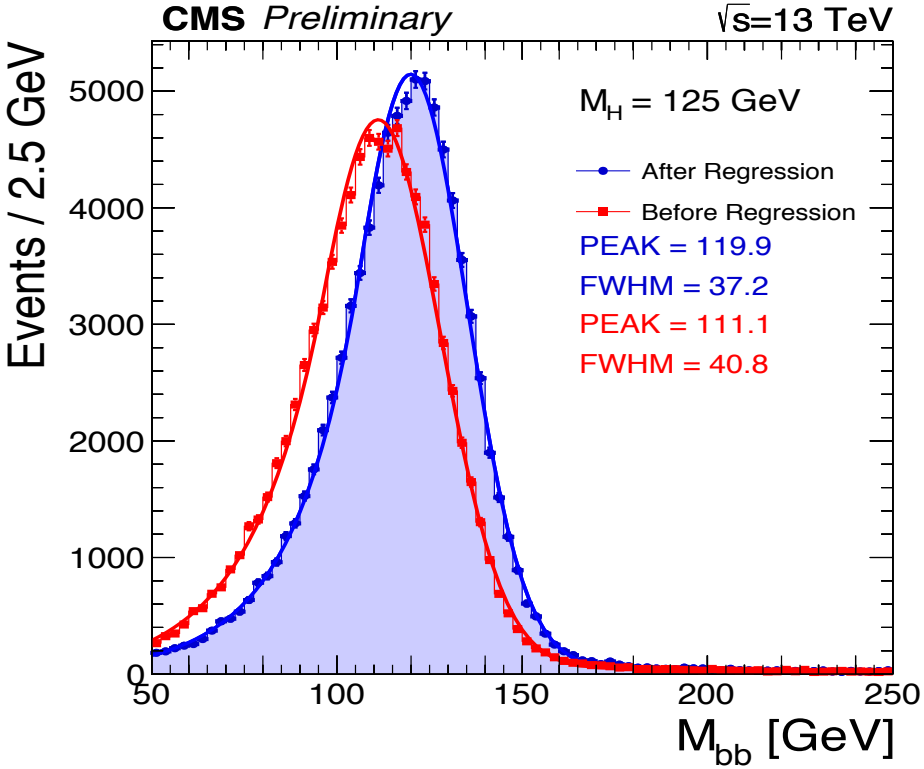
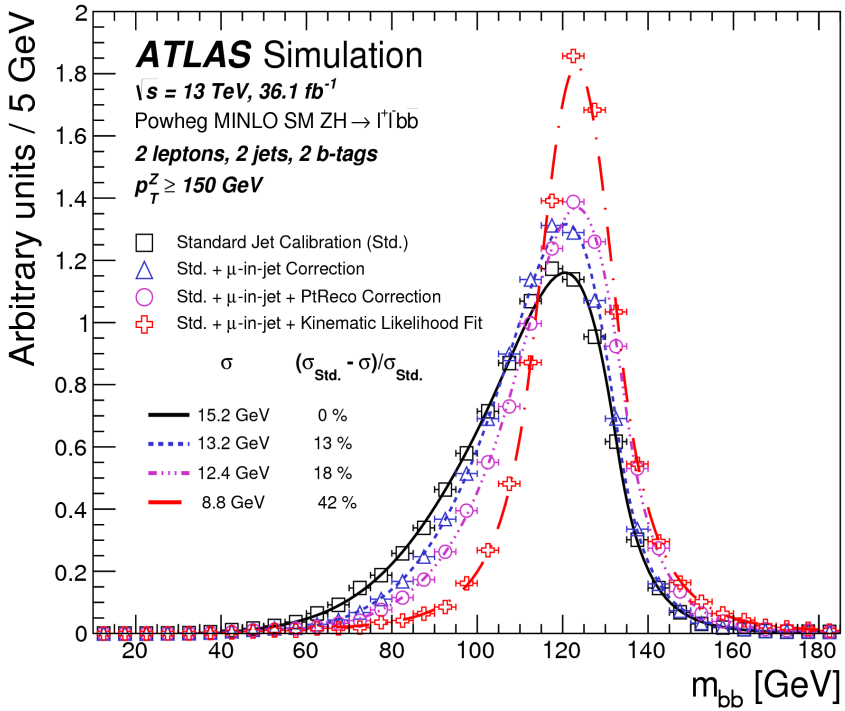
Evidence of SM like Higgs $\rightarrow b\bar{b}$

Submitted to PLB



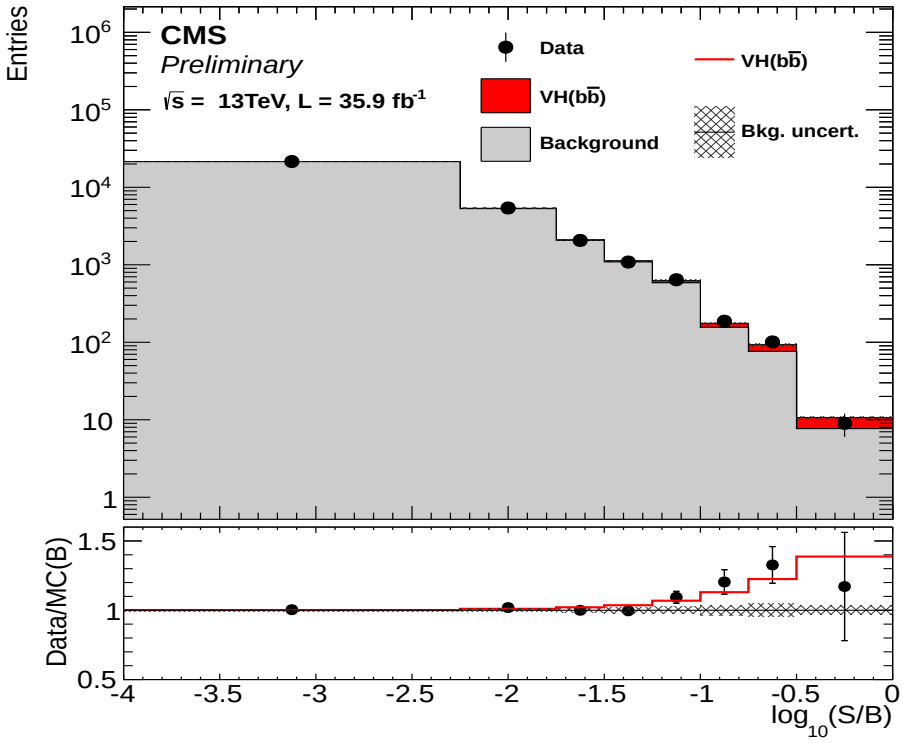
JHEP12(2017)024



- Evidence for $H \rightarrow b\bar{b}$ has been seen in ATLAS/CMS independently with the combination of vector boson association production modes, Z($\nu\nu$)H, W($\nu\mu$)H, W(eμ)H, Z($\mu\mu$)H and Z(ee)H.
- dijet invariant mass distribution for simulated sample of ZH(125), $H \rightarrow b\bar{b}$ with with improved b-jet reconstruction.

Evidence of SM like Higgs $\to b\bar{b}$

Submitted to PLB



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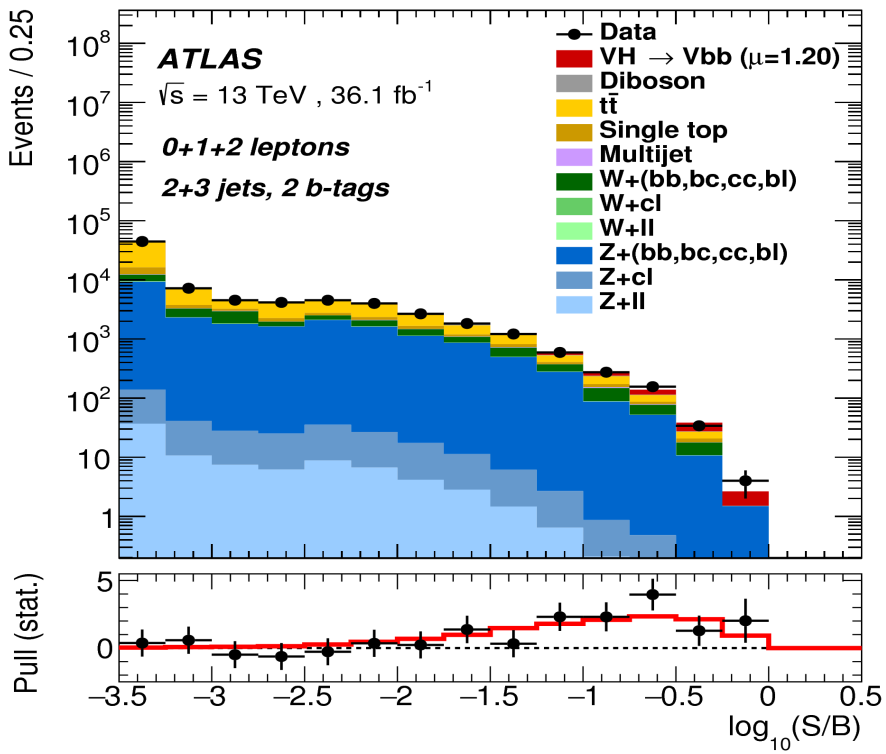
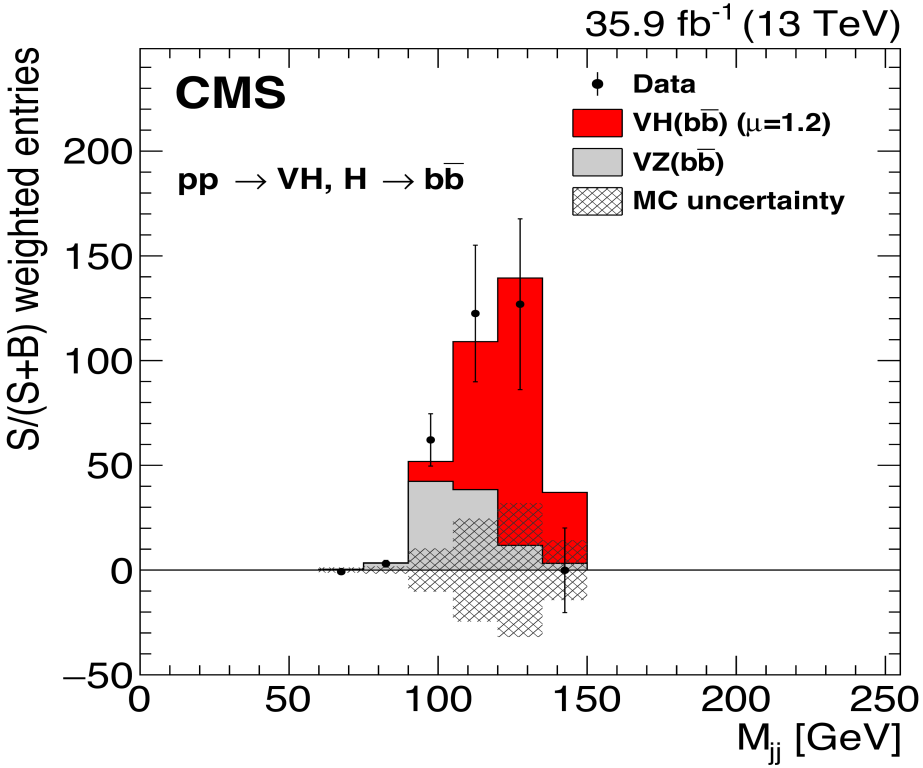


- 3 categories have been used.
  - 0 lepton channel, targets $Z_{\nu\nu}$ H Events;
  - 1 lepton channel, targets $W(l\nu)H$ events;
  - 2 lepton channel, targets $Z(ll)H$ decays.
- Measurement of VZ with $Z(bb)$ reached 5σ from both CMS/ATLAS, serves as a validation of the methodology used in the VH search.

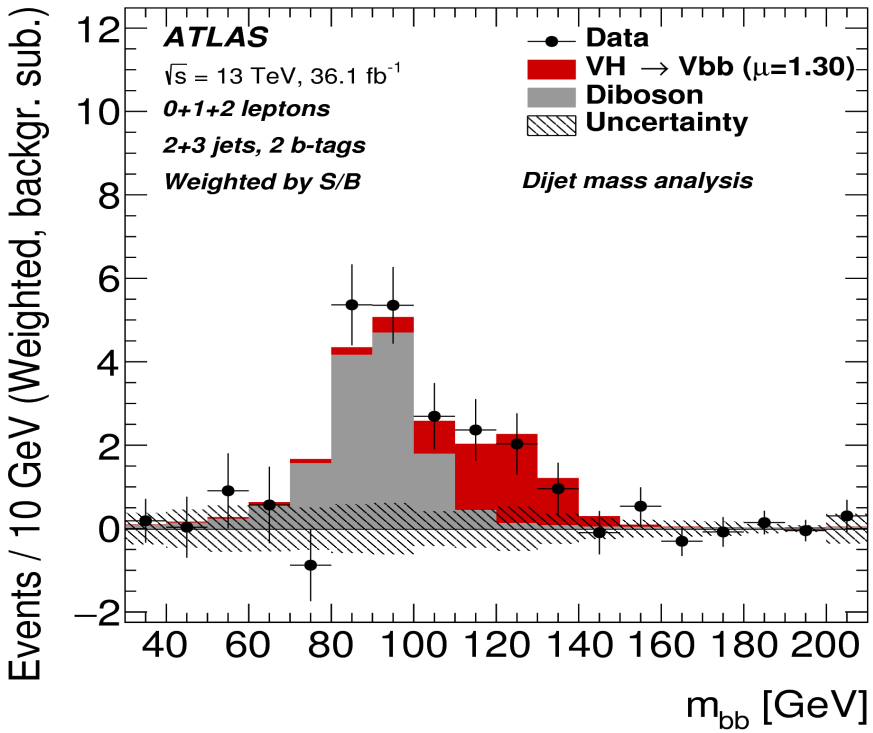
Evidence of Higgs $\to b\bar{b}$

Submitted to PLB



- a significance of 3.3σ has been seen. Combine with Run 1 result, 3.8σ.

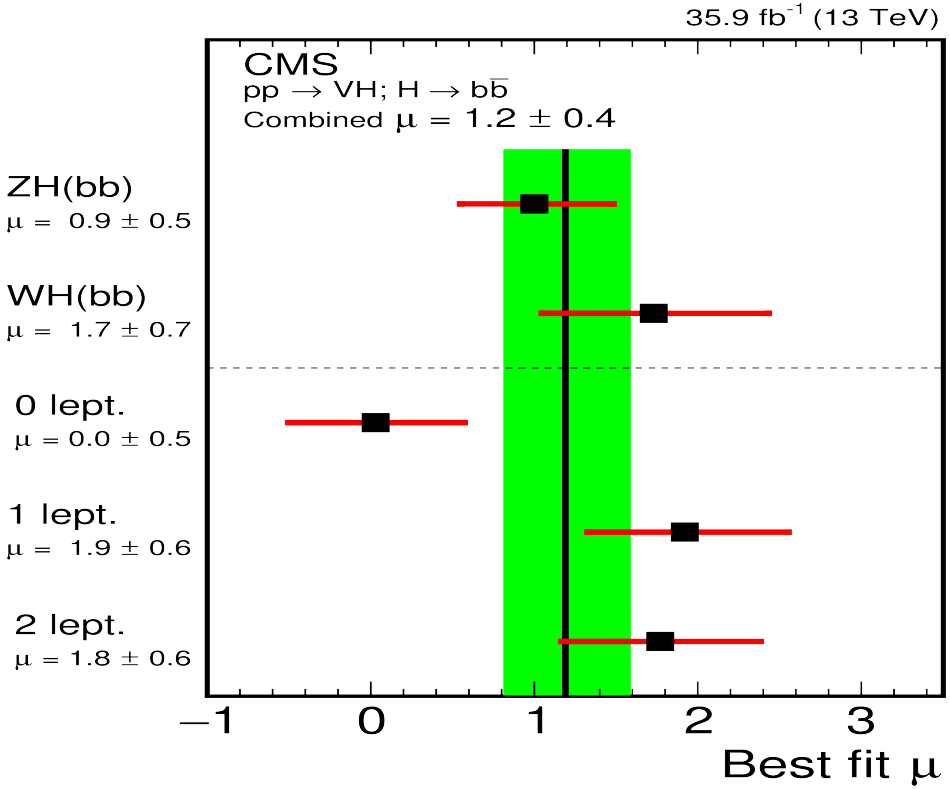
JHEP12(2017)024



- a significance of 3.5σ has been seen. Combine with Run 1 result, 3.6σ.

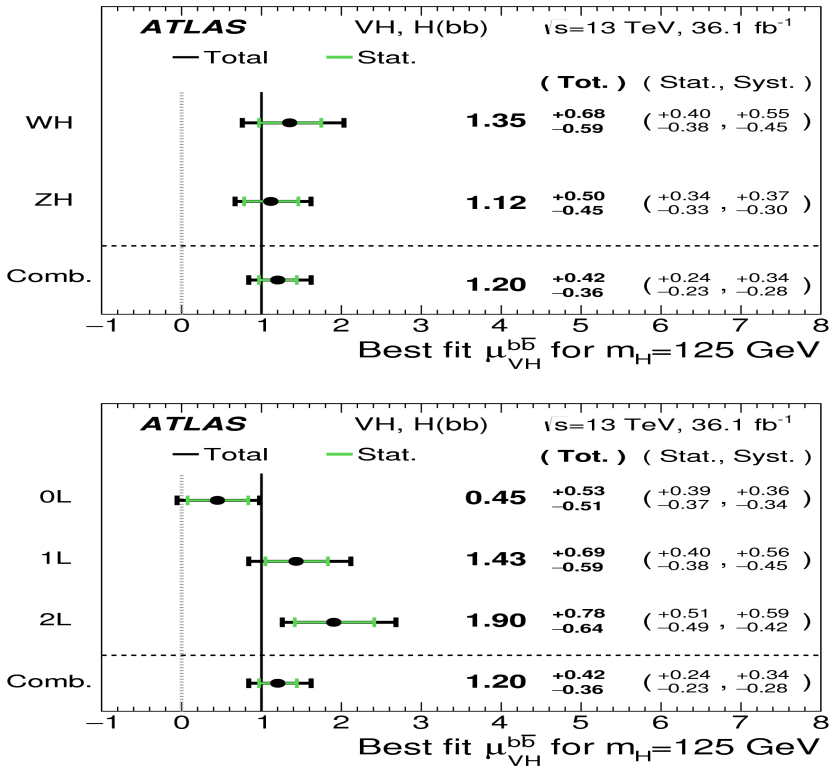
Evidence of Higgs $\to b\bar{b}$

Submitted to PLB



- Best fit $\mu = 1.2 \pm 0.4$.
- Combined with Run 1 result, $\mu = 1.06^{+0.31}_{-0.29}$.

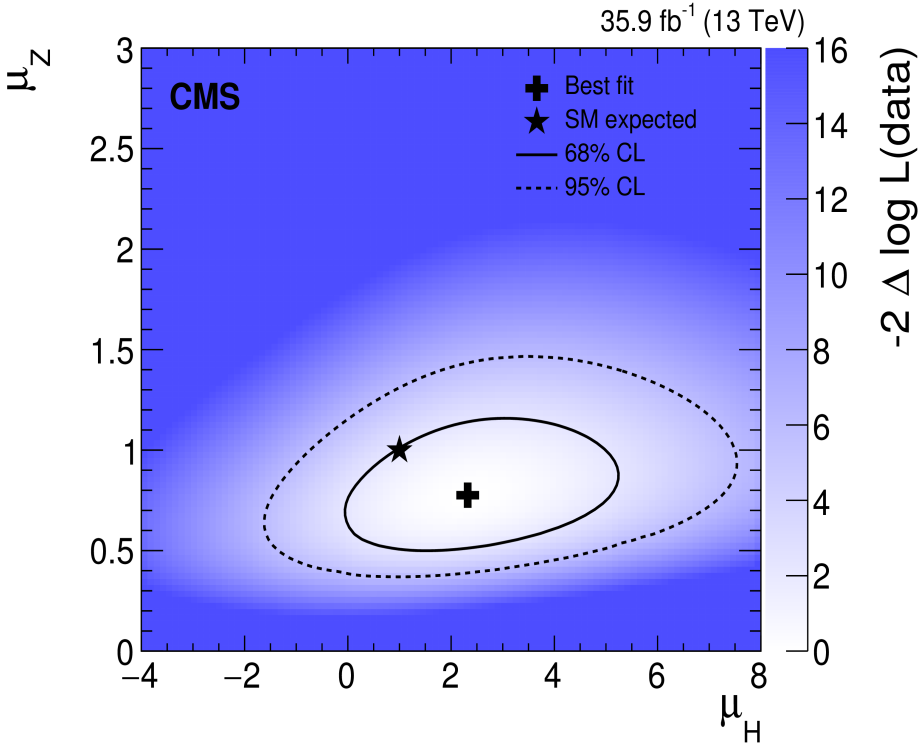
JHEP12(2017)024



- $\mu = 1.2^{+0.24}_{-0.23}(stat.)^{+0.34}_{-0.28}(syst.)$
- Combined with Run 1 result, $\mu = 1.11^{+0.12}_{-0.11}(stat.)^{+0.22}_{-0.19}(syst.)$

Searching for Boosted Hbb

Submitted to PRL



- Inclusive search for H(125) with boosted topology. Targeting for Higgs with $p_T > 450$ GeV.
- Significance: 1.5σ (0.7σ exp). Consistent with SM prediction.
- Boosted fat jet required, with substructure and jet grooming.
- Validated by the boosted $Z \to b\bar{b}$.

- by-production: the $Z(b\bar{b})$ is observed for the first time in the single-jet topology.
  - local significance of 5.1σ (5.8 expected), $\mu_z = 0.78^{+0.23}_{-0.19}$.

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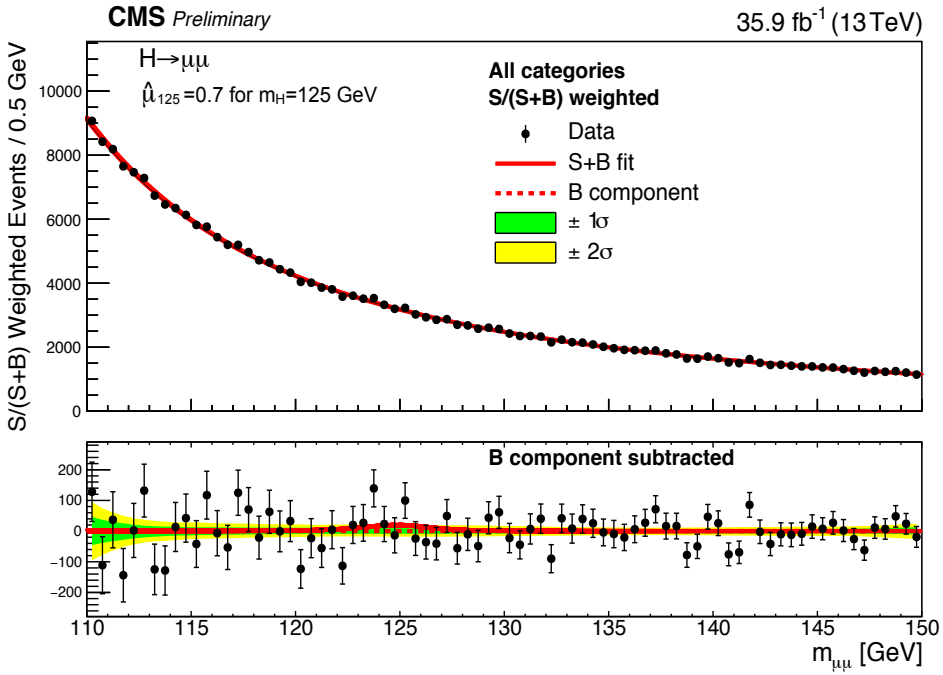
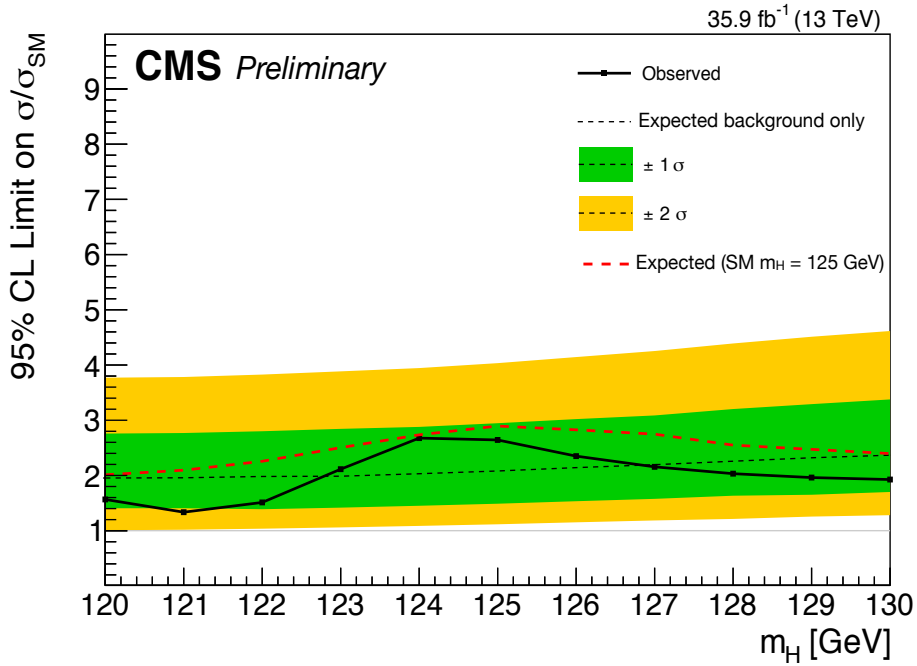
PDG μ update, Higgs $\rightarrow \mu\mu$

CMS-PAS-HIG-17-019

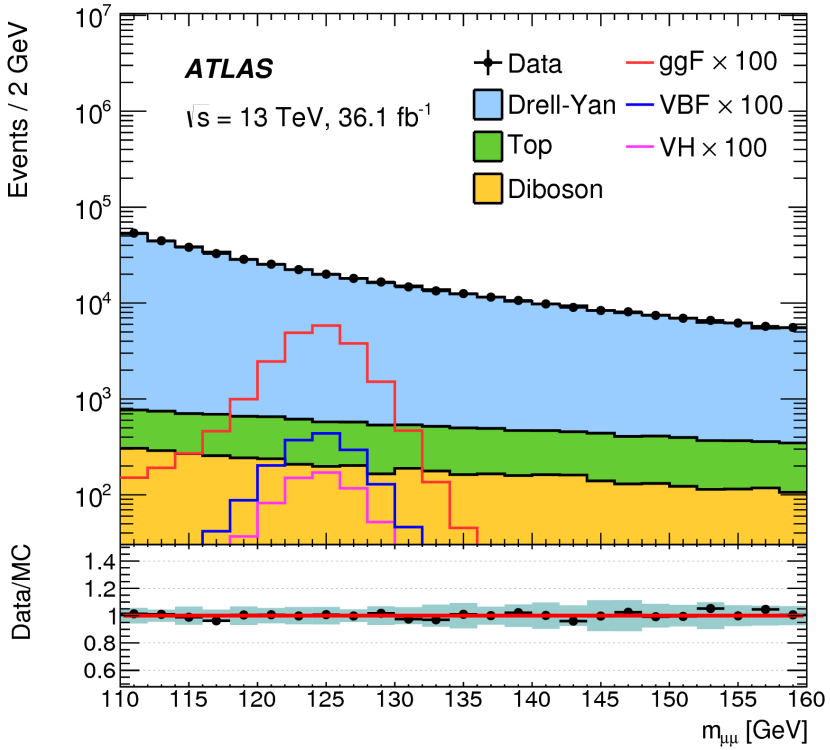


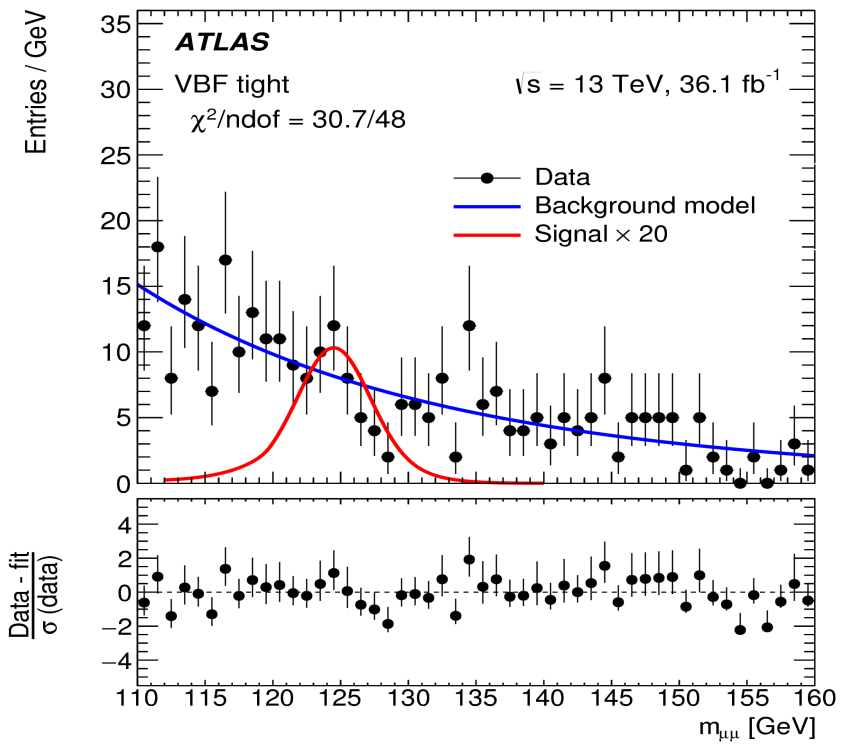


- signal strength is measured to be $\mu_{125}^{comb} = 0.9^{+1.0}_{-0.9}$, giving a strong improvement on Run 1 result (0.1 ± 2.5).

PDG μ update, Higgs $\rightarrow \mu\mu$

PRL 119(2017)051802





- 4 ggH+ 2 VBF categories have been explored with ATLAS.
- Combined with Run 1 data, the observed(expected) upper limit is $2.8(2.9)\sigma$. And the μ is measured to be -0.1 ± 1.4.

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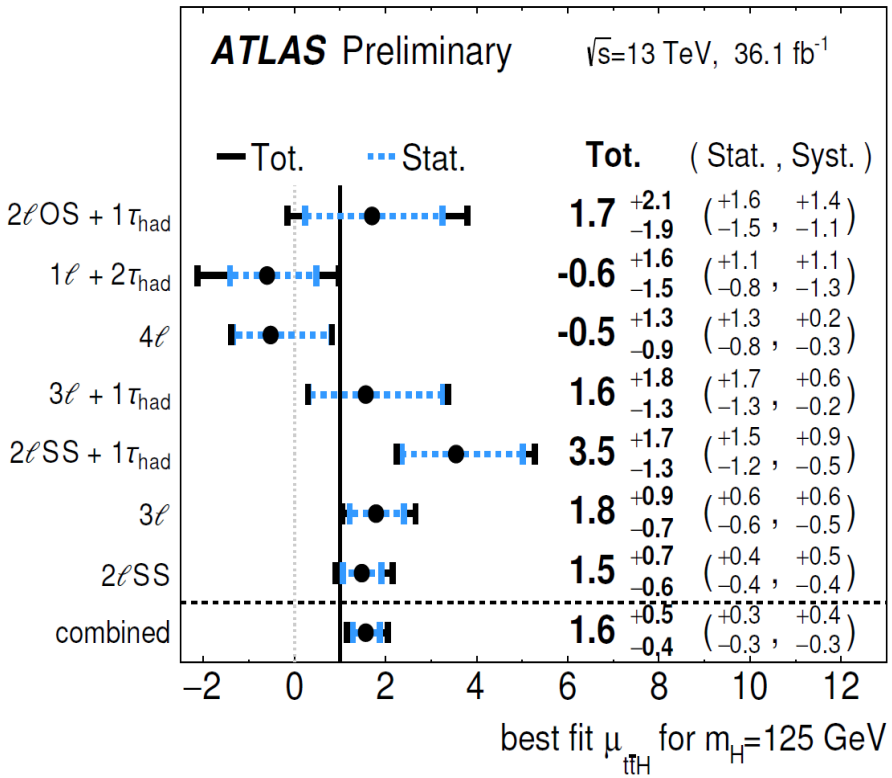
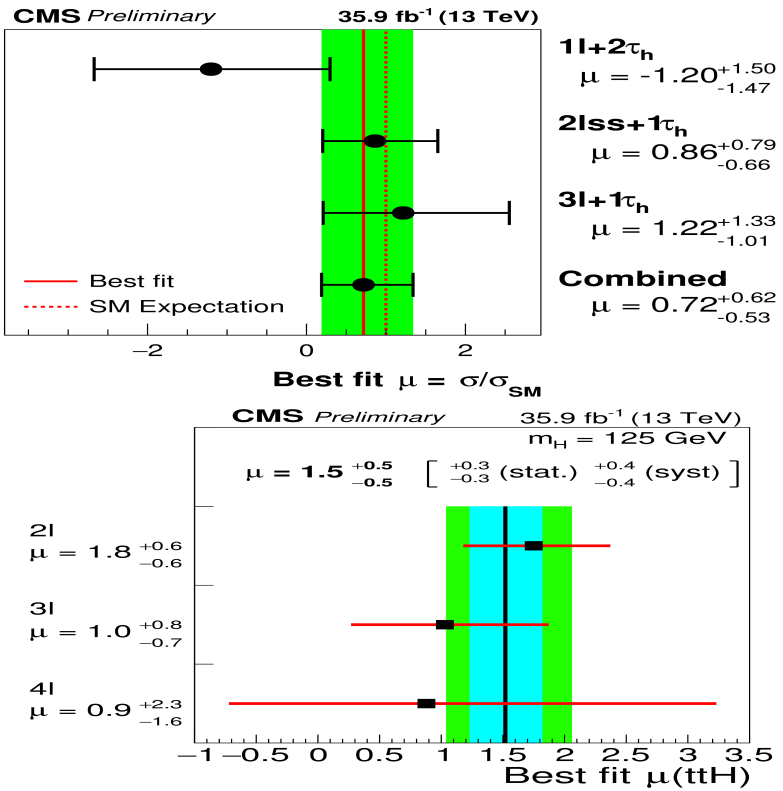
Top pair associated Higgs production

ATLAS-CONF-2017-077



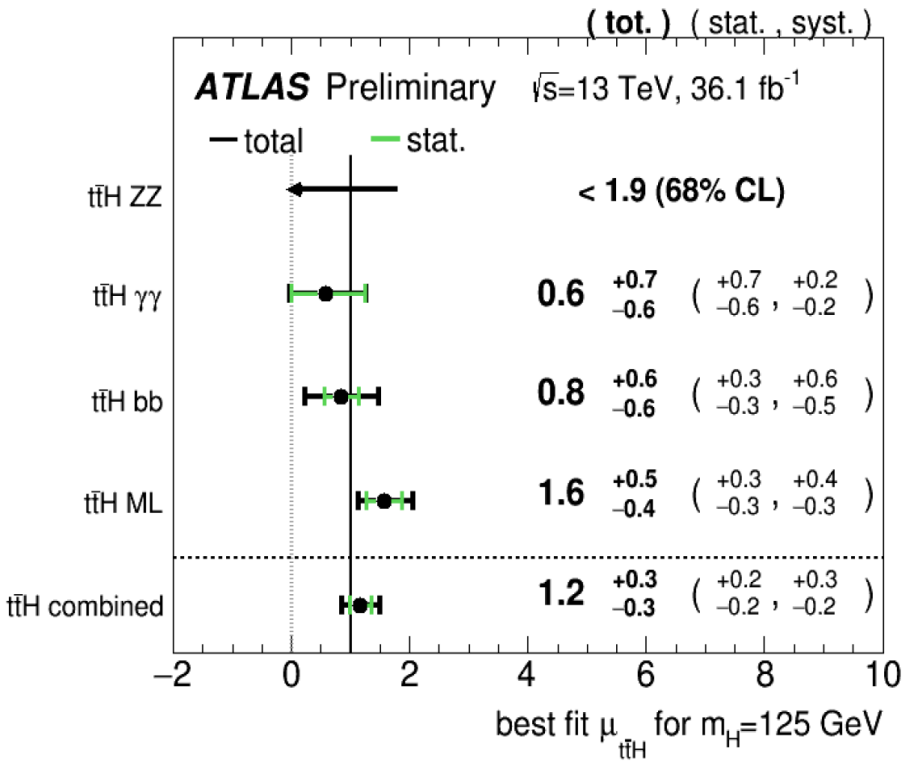
CMS-PAS-HIG-003/004/005



- targeting for $H \to ZZ$, WW and $\tau\tau$ decay modes
- complicated final states, with evidences of
  - 3.3σ (2.5 σ exp.) from CMS and 4.3σ(2.8 σ exp.) from ATLAS.

Top/Top pair associated Higgs production

ATLAS-CONF-2017-077



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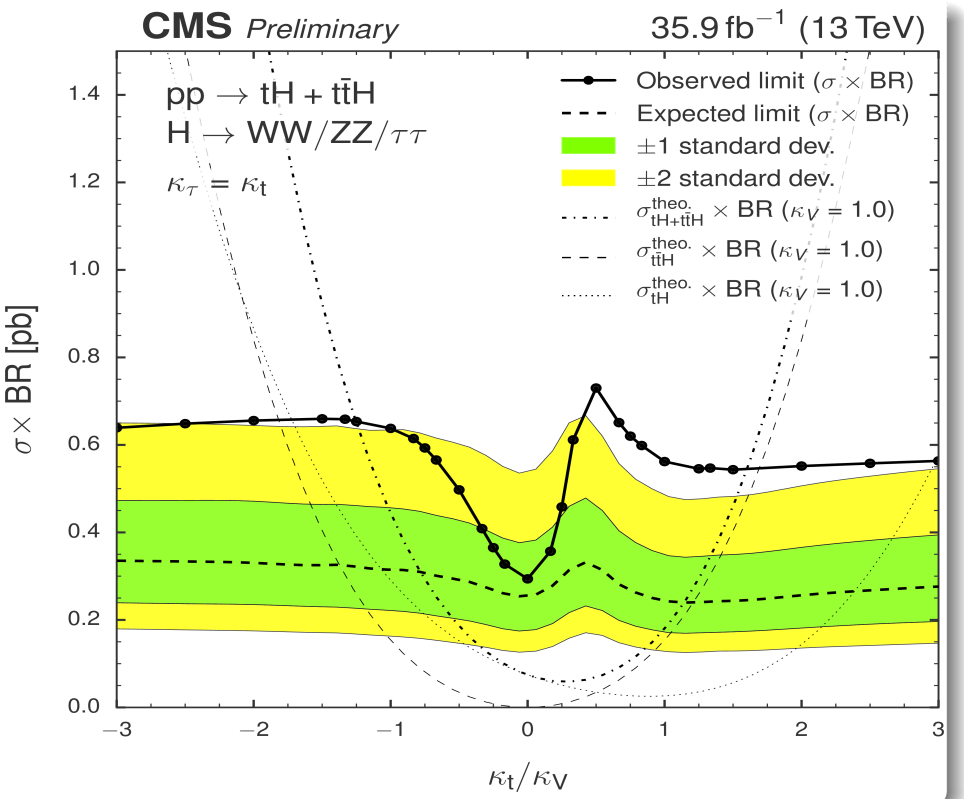

- Combined with $\gamma\gamma$, $b\bar{b}$ and ZZ reaches 4.2σ with 3.8σ expected.
- UL of combined cross section of tH+ttH times BR has been measured to 0.64 pb with 0.32 pb expected at 95% CL.

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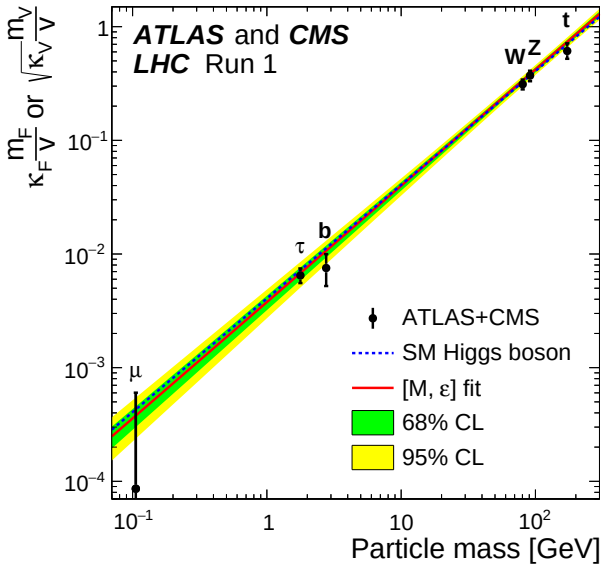

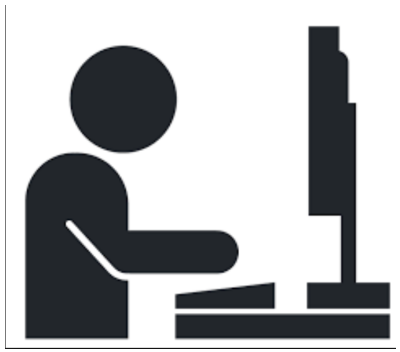

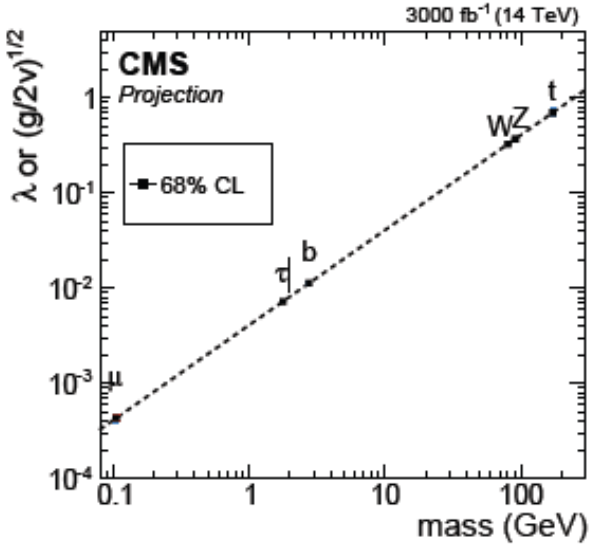

- LHC is an unique and ideal place for Higgs Physics, today.
- Rediscoveries of Higgs boson have been reloaded with $35.9 fb^{-1}$ 2016 data. Fermionic decay modes of SM like Higgs boson have been established in LHC.
- We could get a better understanding with LHC Run 2 data of SM like Higgs boson with more differential measurements, and also to physics beyond ...
  - *see the following talk from Prof. Shu LI (SJTU) from ATLAS .*


Thanks for your attention!