Recent physics highlights from ATLAS

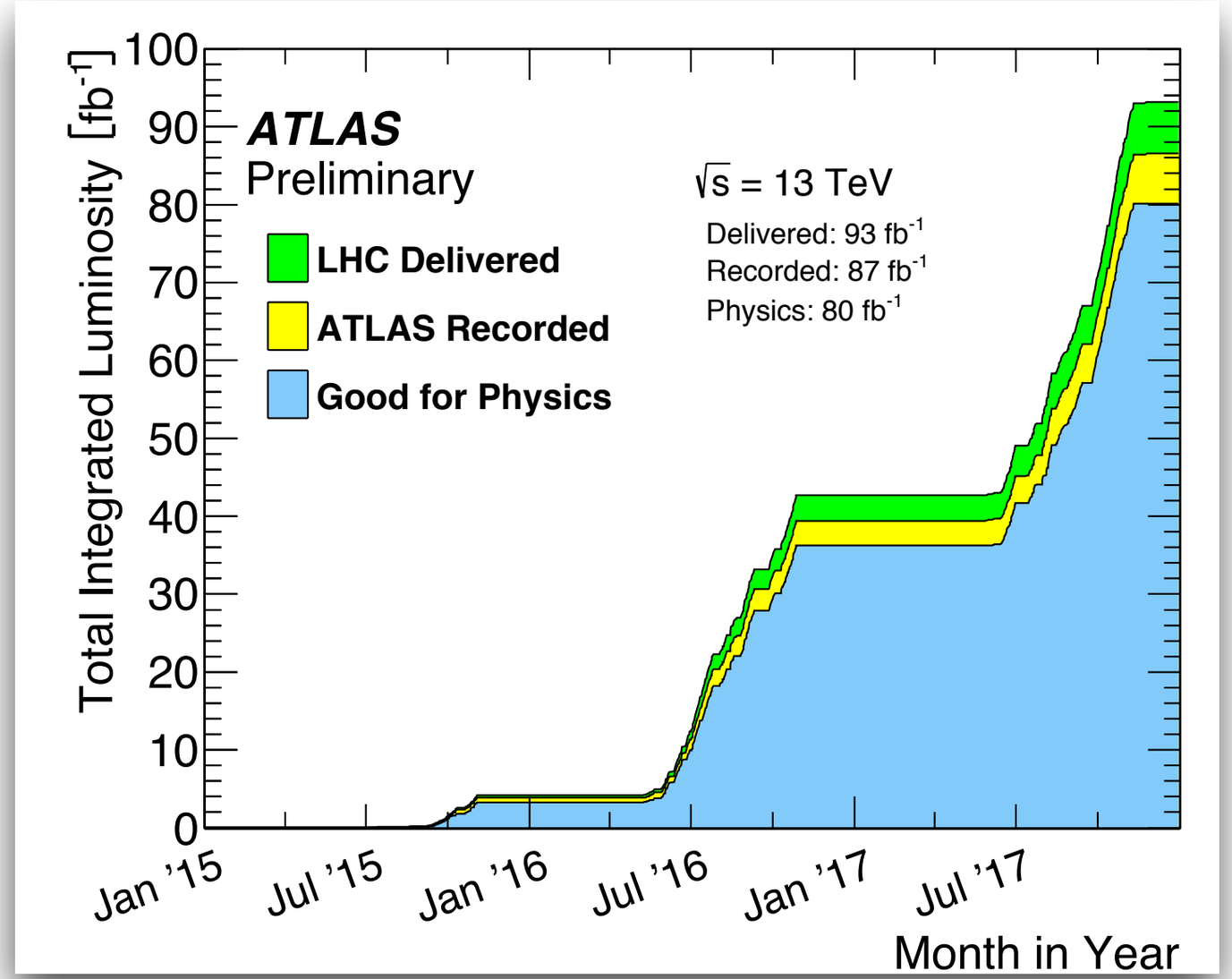
Valerio Dao (CERN)
on behalf of the ATLAS Collaboration

Symposium 25 Years of LHC Experimental Programme

CERN

15-12-2017

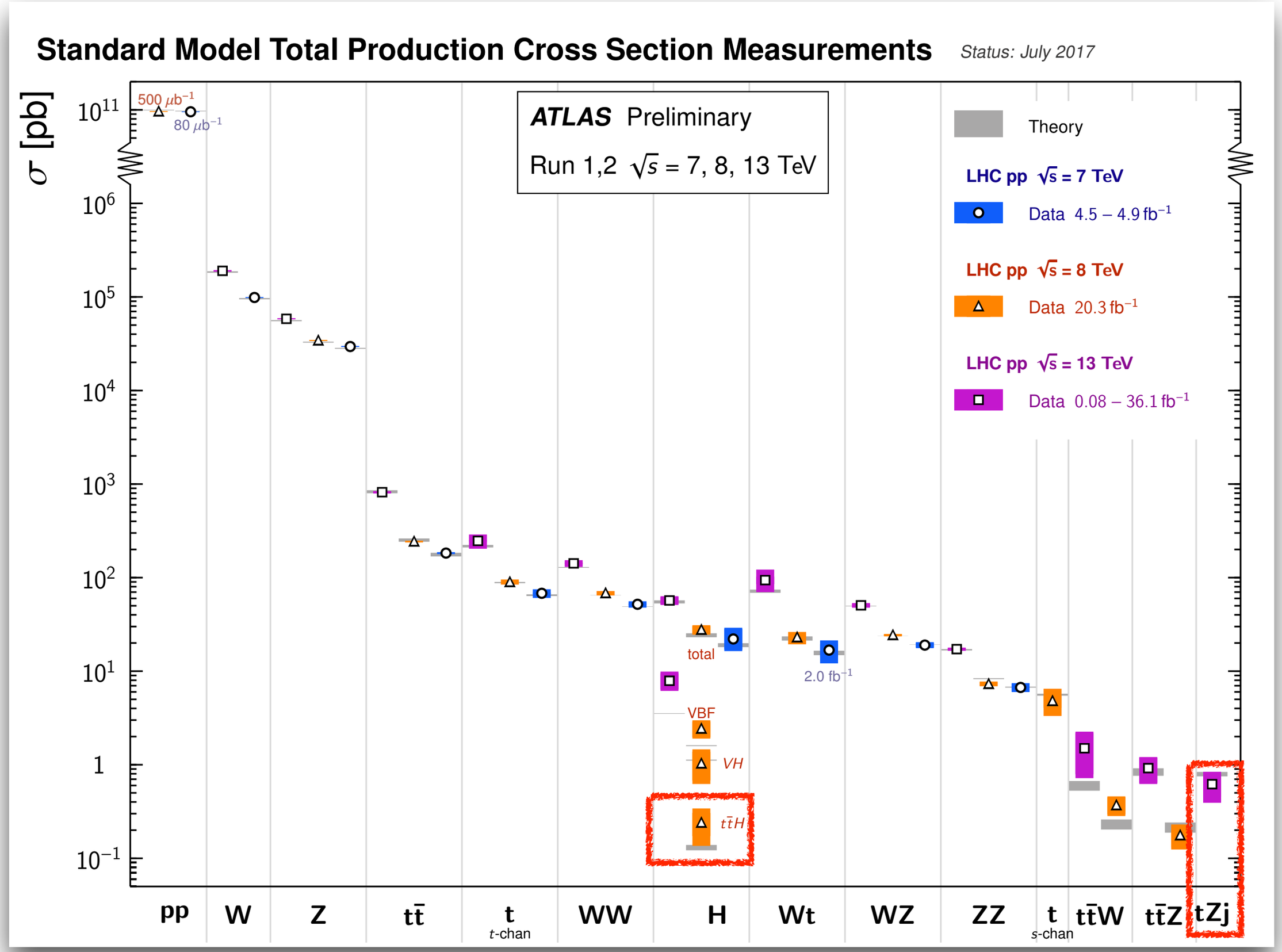
Another great and busy year for ATLAS



- *Harvesting **Run 1** measurements reaching unprecedented precision*
- *Exploiting the full potential of the **2015+2016** data*:
  - constraining the Higgs sector
  - exploring new physics with high sensitivity

- *Successful detector operation in **2017***:
  - ***93.3% data taking efficiency, 93.6% "good-for-Physics"***
  - addressing challenges from higher pileup

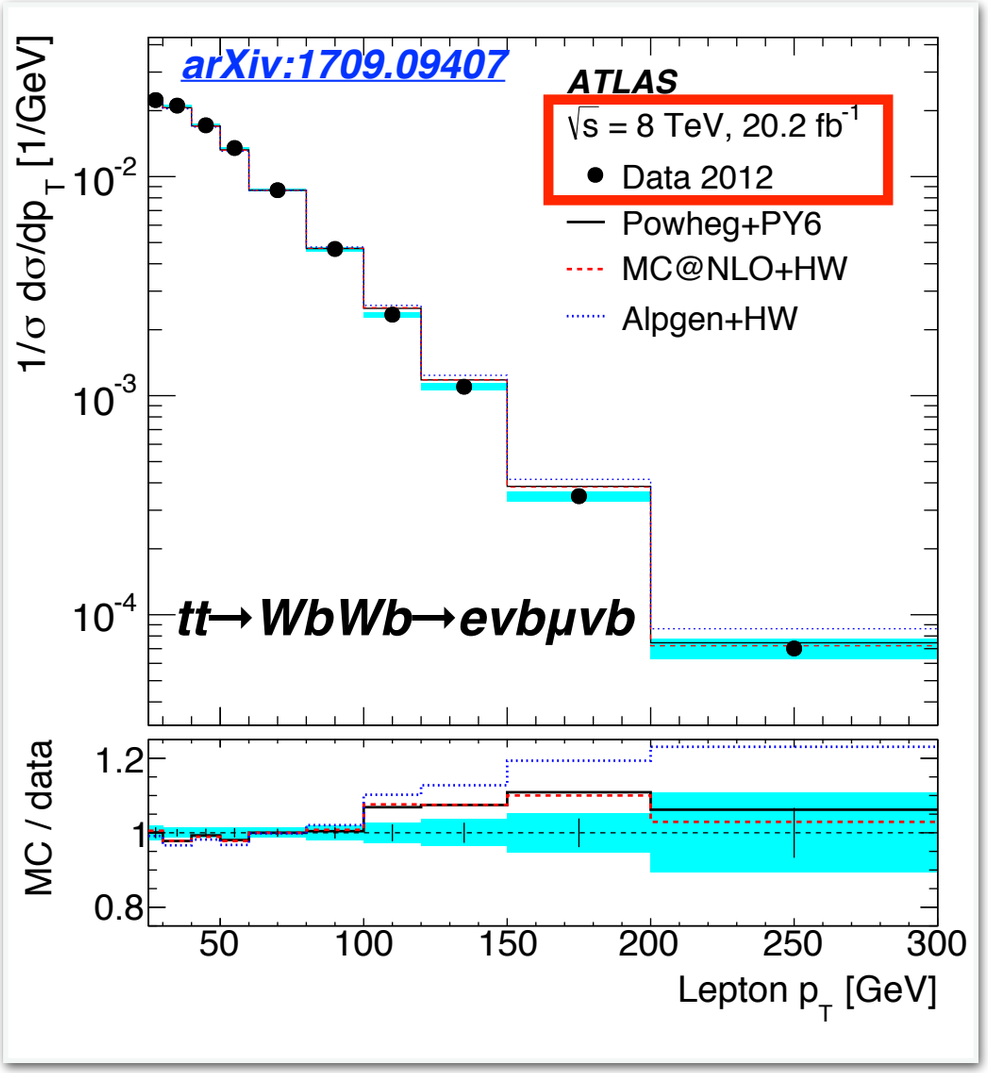
Cross sections: from inclusive …



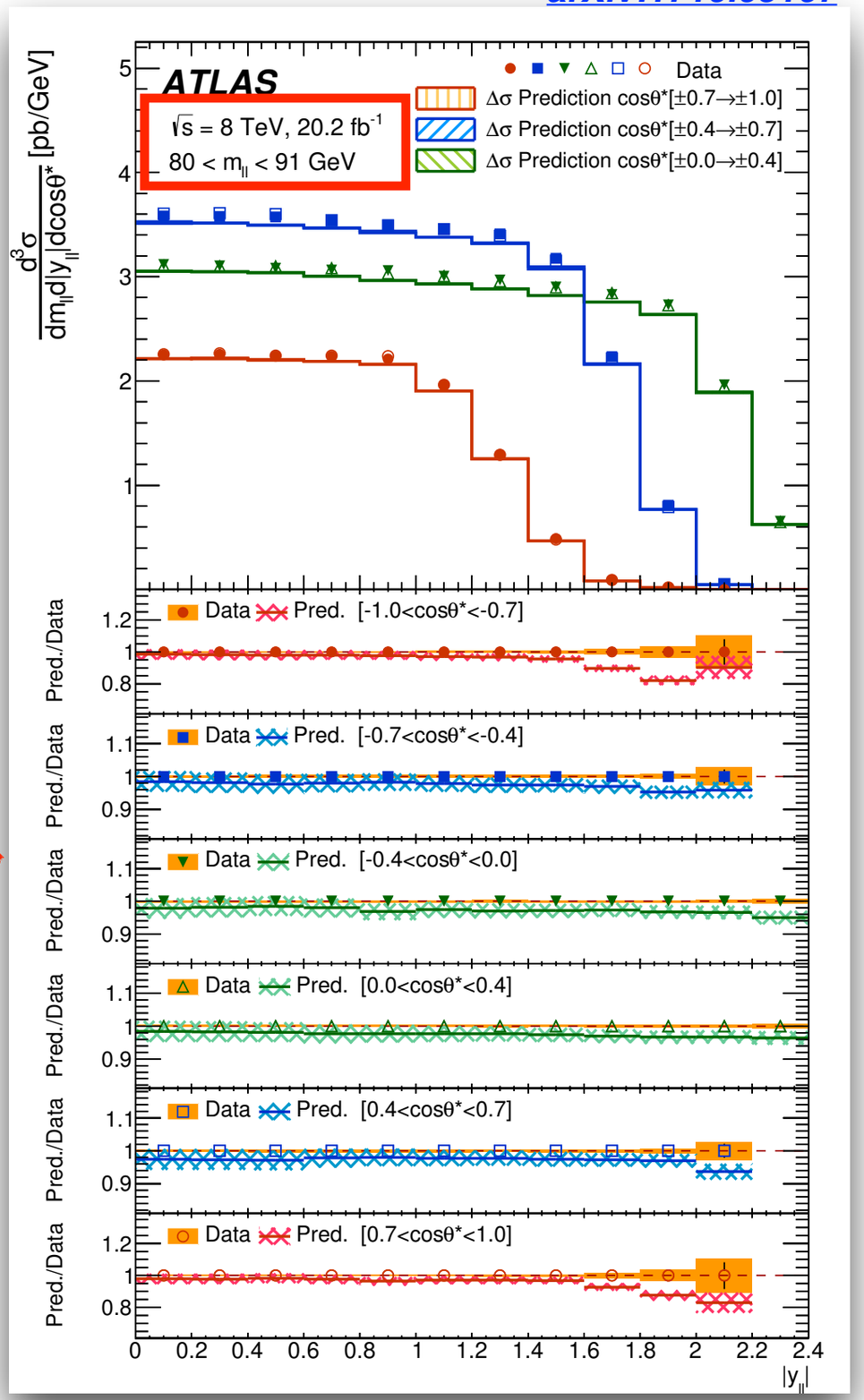
4.2 σ evidence for tZ

Cross sections: … to differential

- **Lepton kinematics in tt events**



arXiv:1710.05167



- **Triple differential Drell-Yan cross section**:

$$d^3\sigma = \frac{d^3\sigma}{dm_{\ell\ell}\, d|y_{\ell\ell}|\, dcos\theta^*}$$

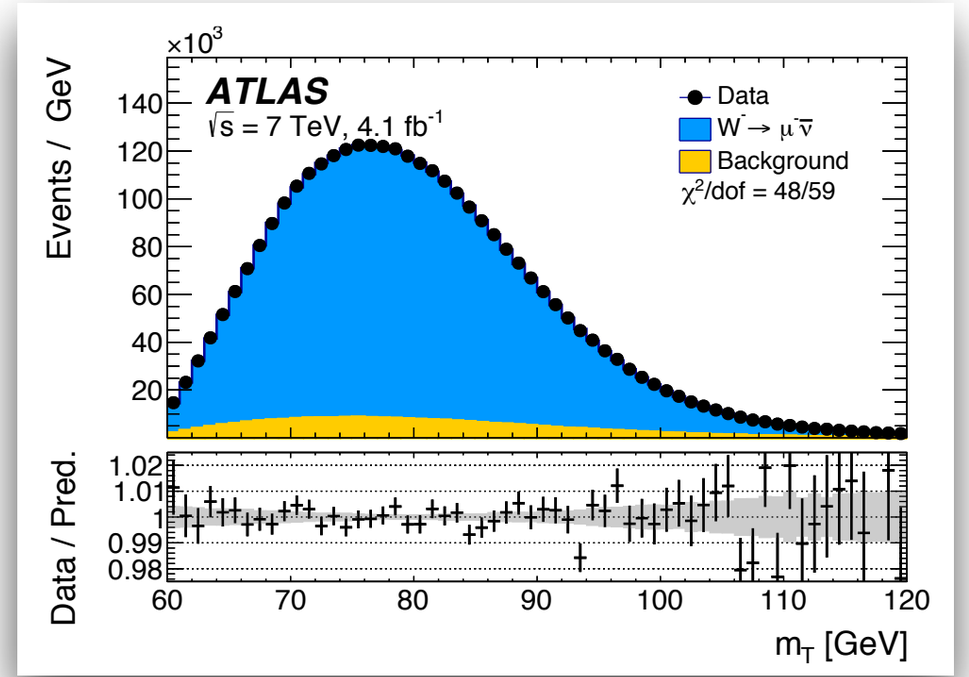
PDF

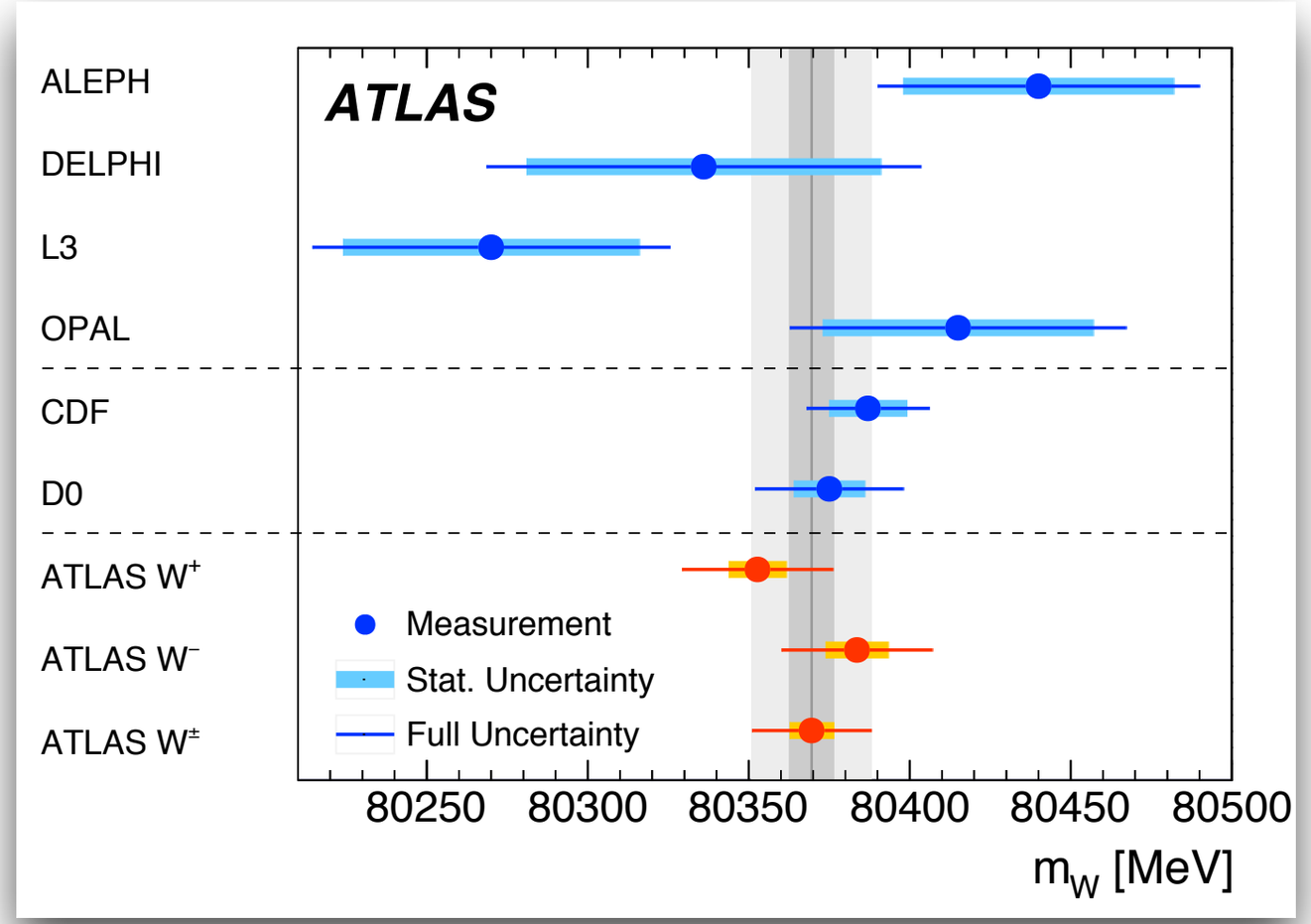
Weak Coupling constant

Z/γ interference

Precision: W boson mass

arXiv:1701.07240





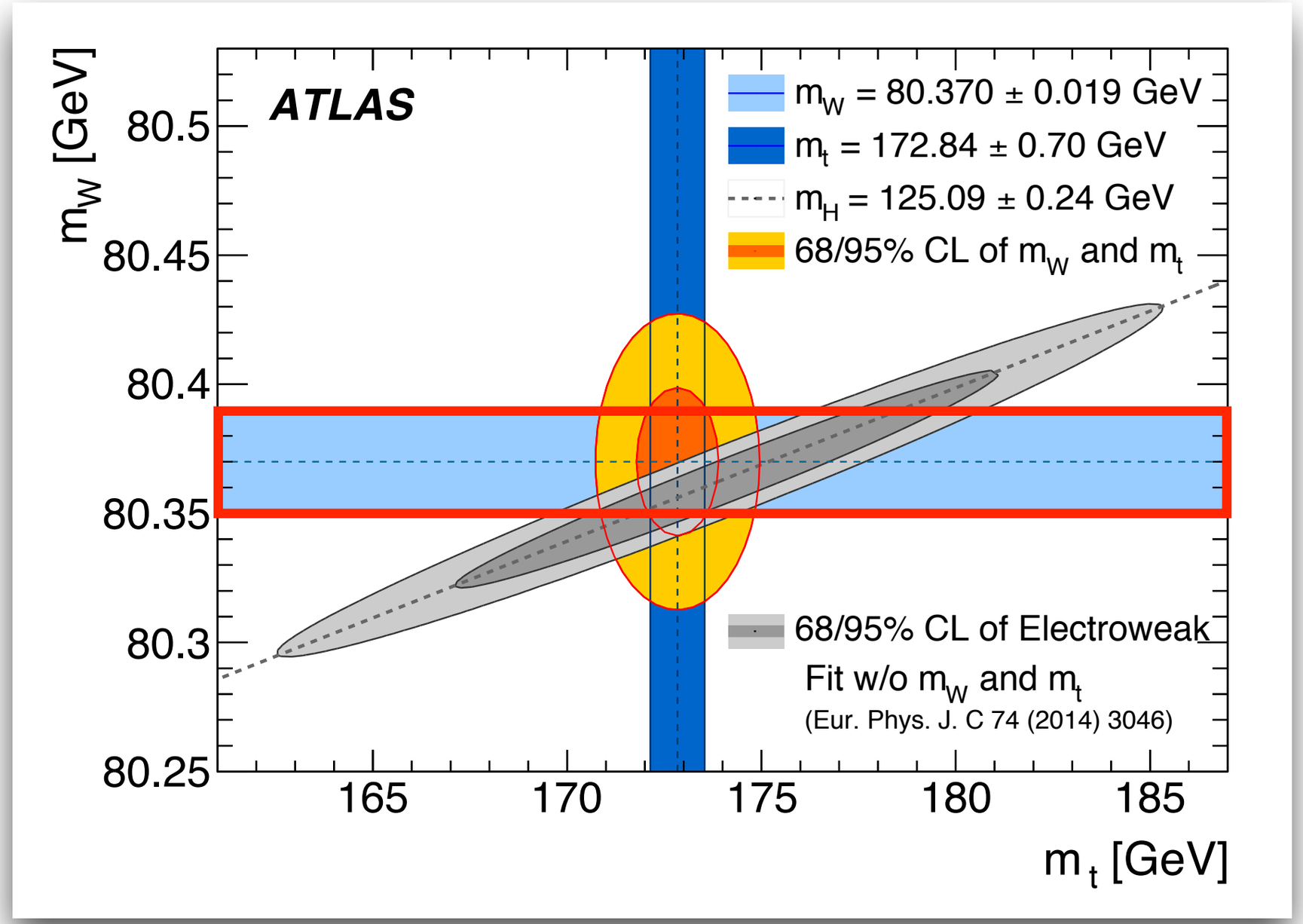
- First measurement at the LHC
- ***Precision comparable with leading measurements from Tevatron***

$$m_W = 80370 \pm 7\ (\text{stat.}) \pm 11\ (\text{exp. syst.}) \pm 14\ (\text{mod. syst.})\ \text{MeV}$$

Total error : 19 MeV (0.02%)

Consistency of SM parameters

- ***m_W, m_{top}, m_H*** *are related to* ***fundamental parameters*** *of the Standard Model and provide key information to* ***test its consistency***



Precision: top quark mass

ATLAS-CONF-2017-071

- m_{top} measured with different tt decay modes:

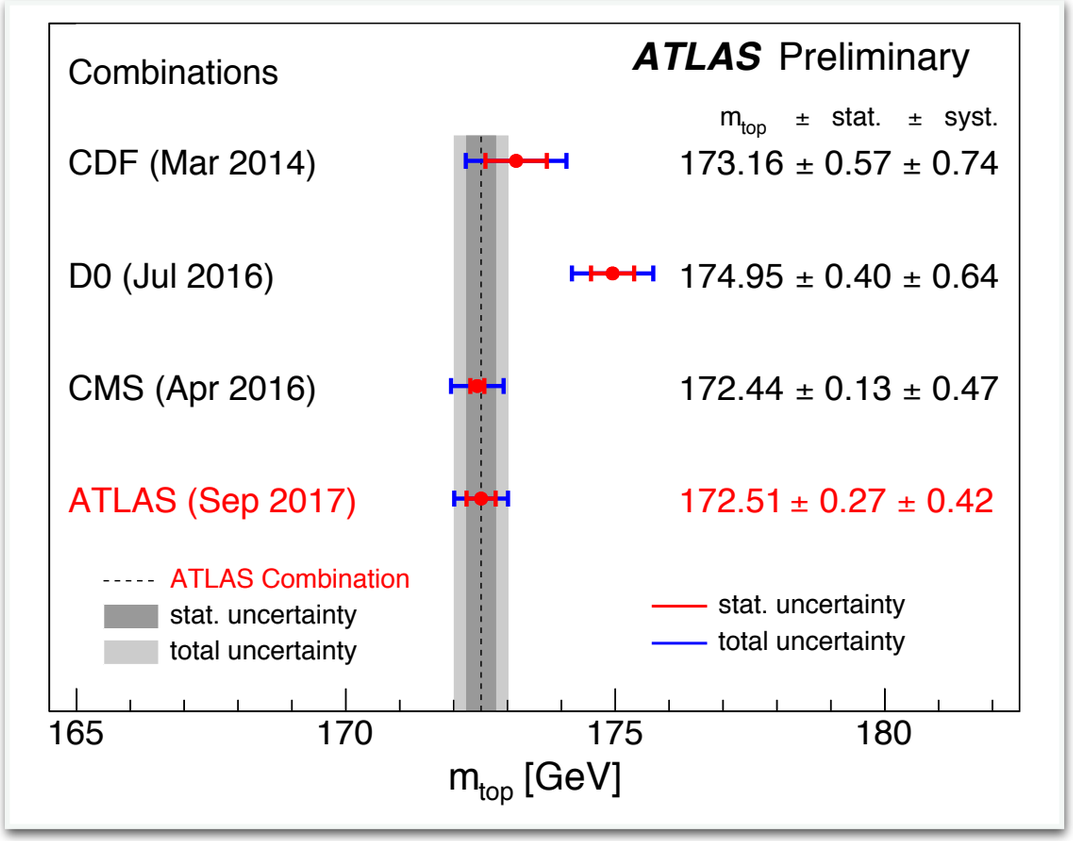
l+jets: $m_{top} = 172.08 \pm 0.39_{stat} \pm 0.82_{syst}$ GeV

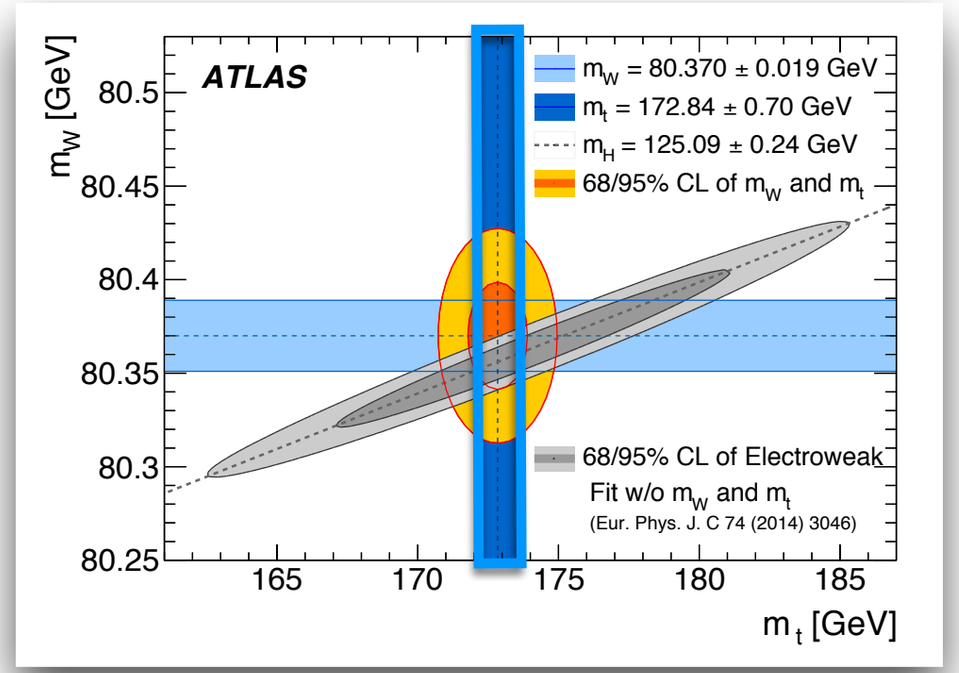
di-lepton: $m_{top} = 172.99 \pm 0.41_{stat} \pm 0.74_{syst}$ GeV

- ***Run1 combination:***

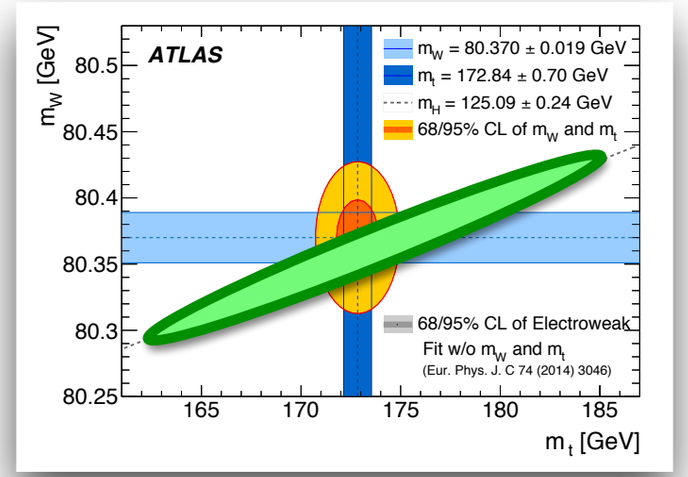
$$m_{top} = 172.51 \pm 0.27_{stat} \pm 0.42_{syst} \text{ GeV}$$

0.3%



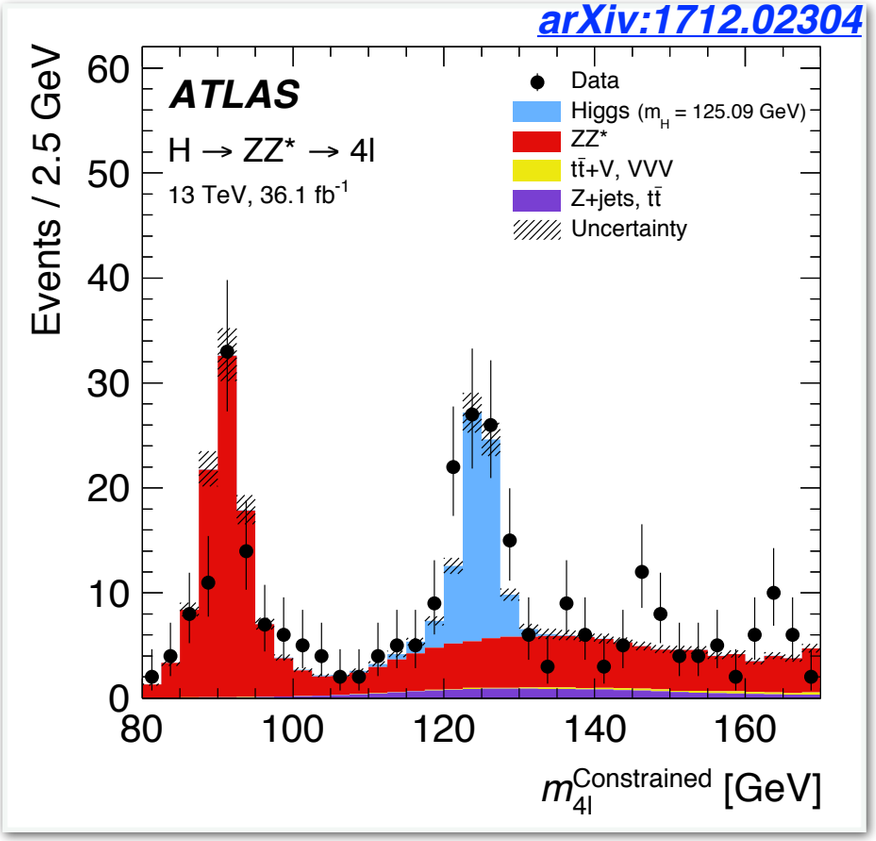


Precision: Higgs boson mass



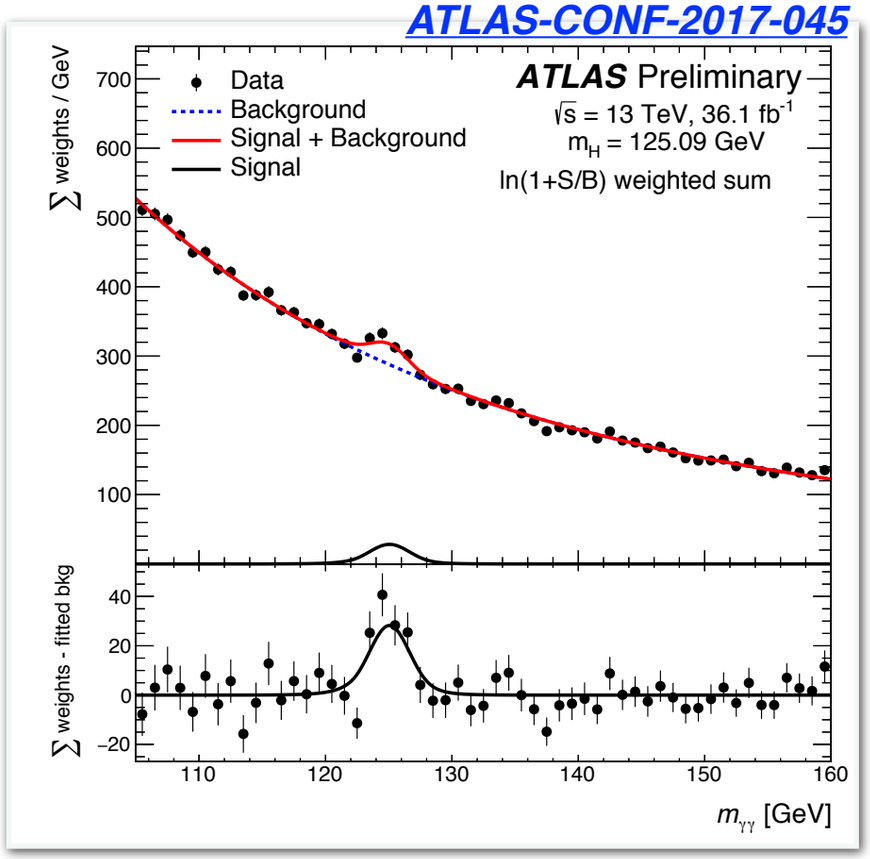
$H \to ZZ^* \to 4l$

arXiv:1712.02304



$H \to \gamma\gamma$

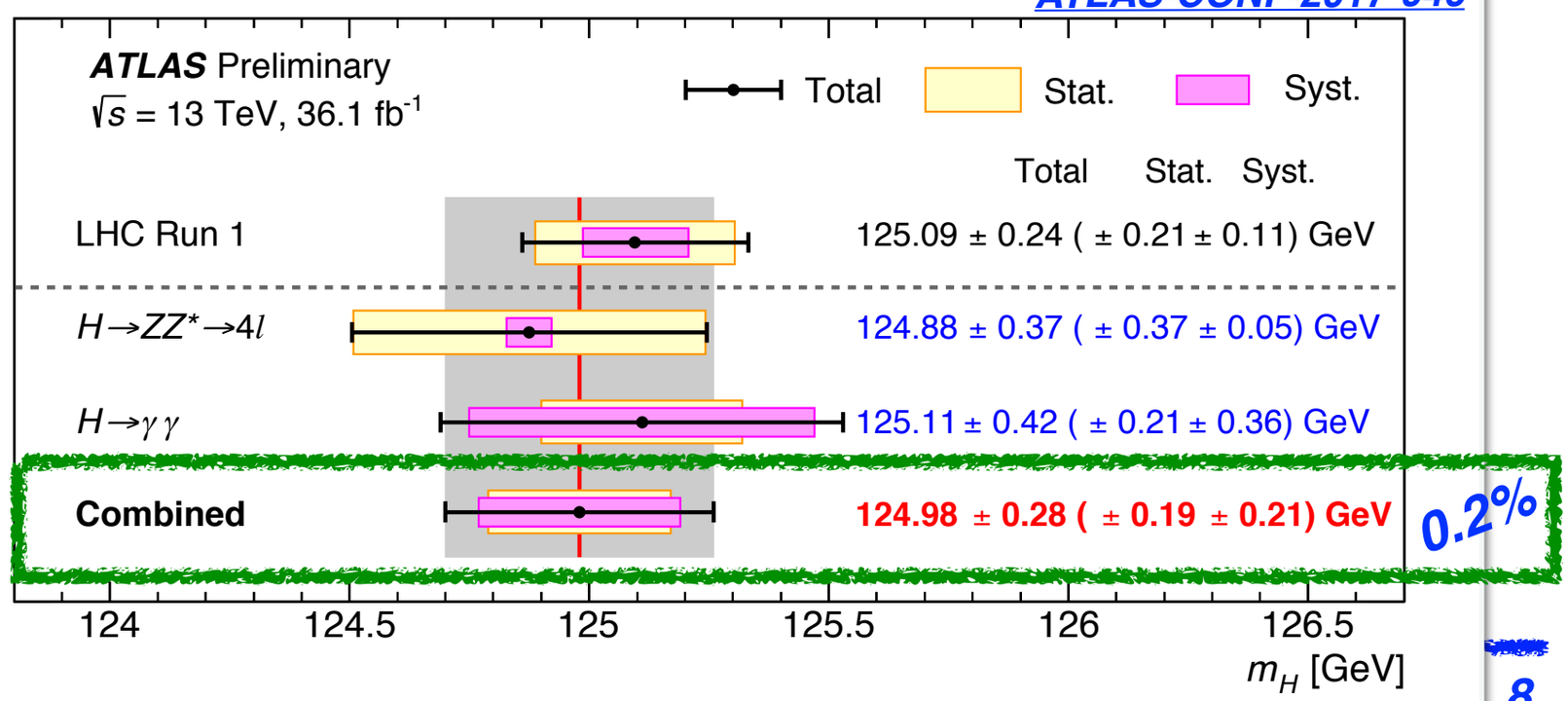
ATLAS-CONF-2017-045



- Preliminary Run-2 result approaching Run-1 legacy ATLAS+CMS measurement

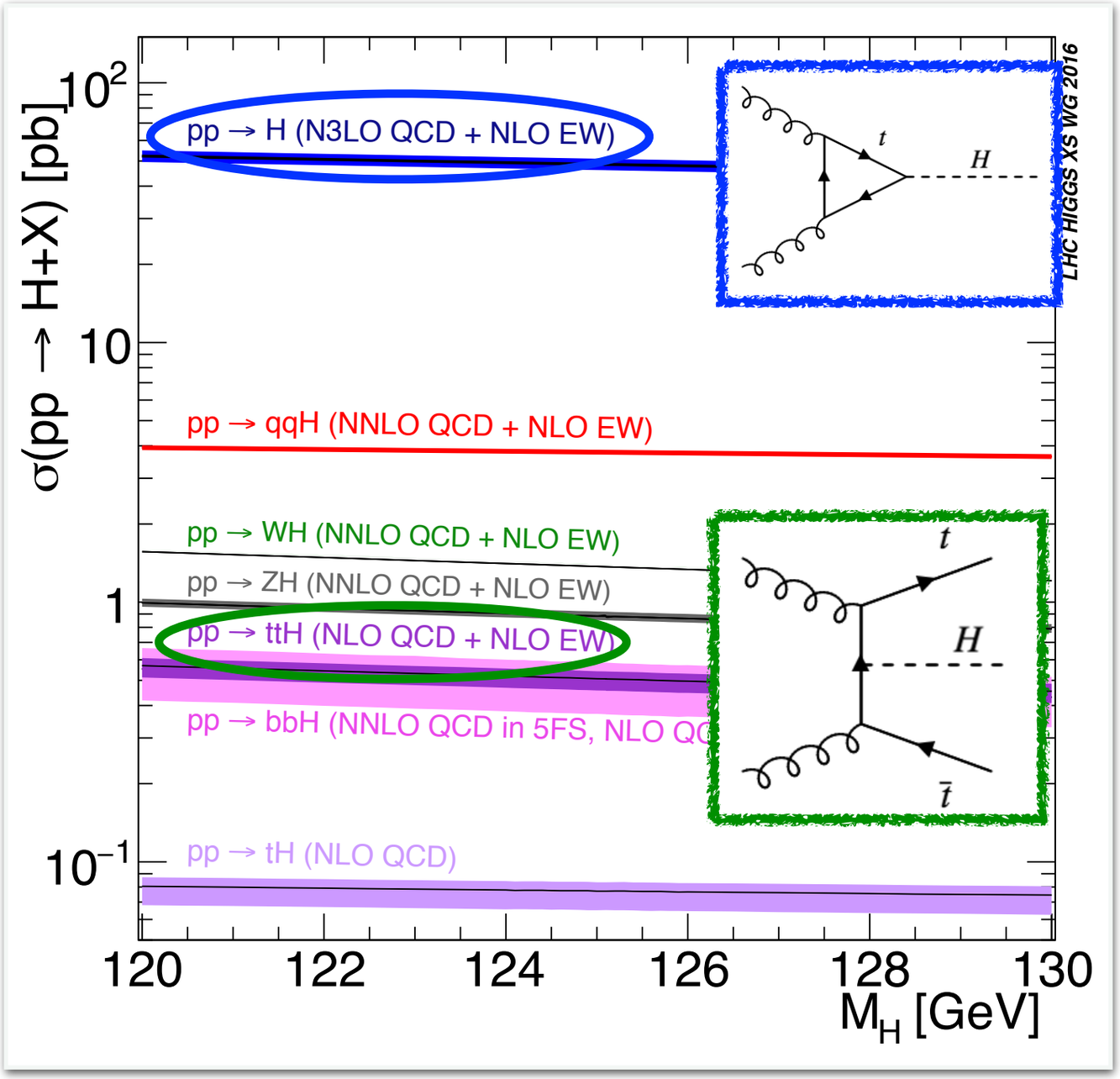
- *Higgs boson precision channels well established at 13 TeV*

ATLAS-CONF-2017-046

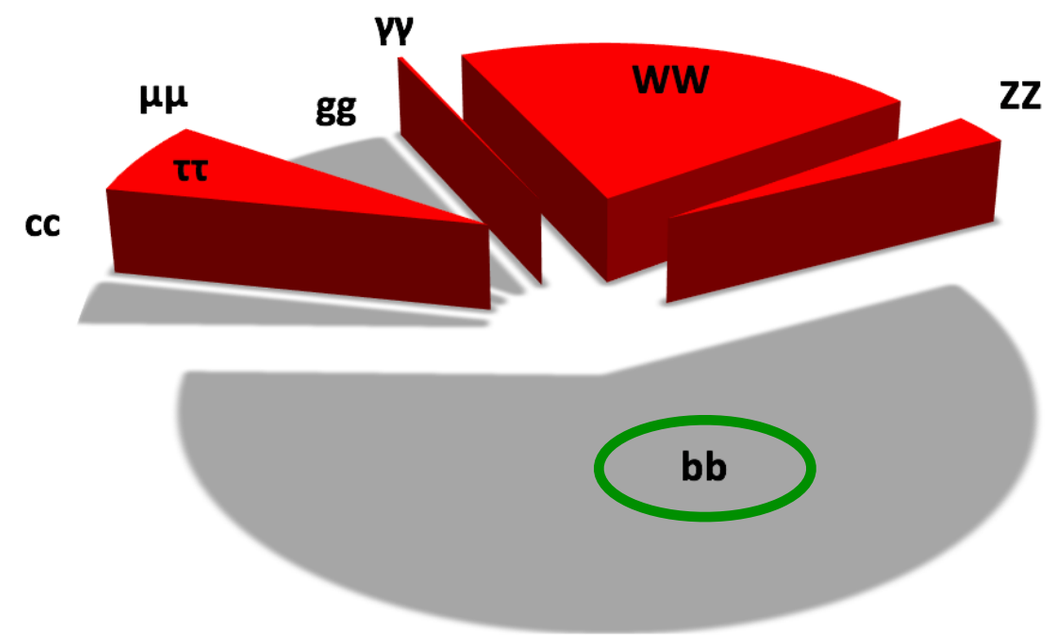


Snapshot of the Higgs boson landscape: Run I

- The success of the Run 1 results relied on clean *bosonic decay modes* and *leading production mechanisms*
- Many more aspects of the Higgs sector still to be explored: ***direct coupling to quarks***



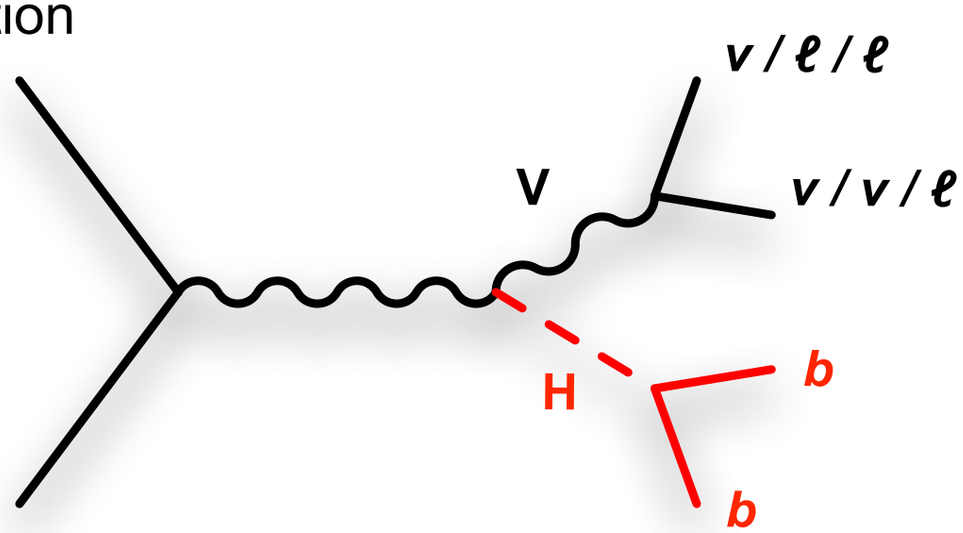
Observed decays: 31%

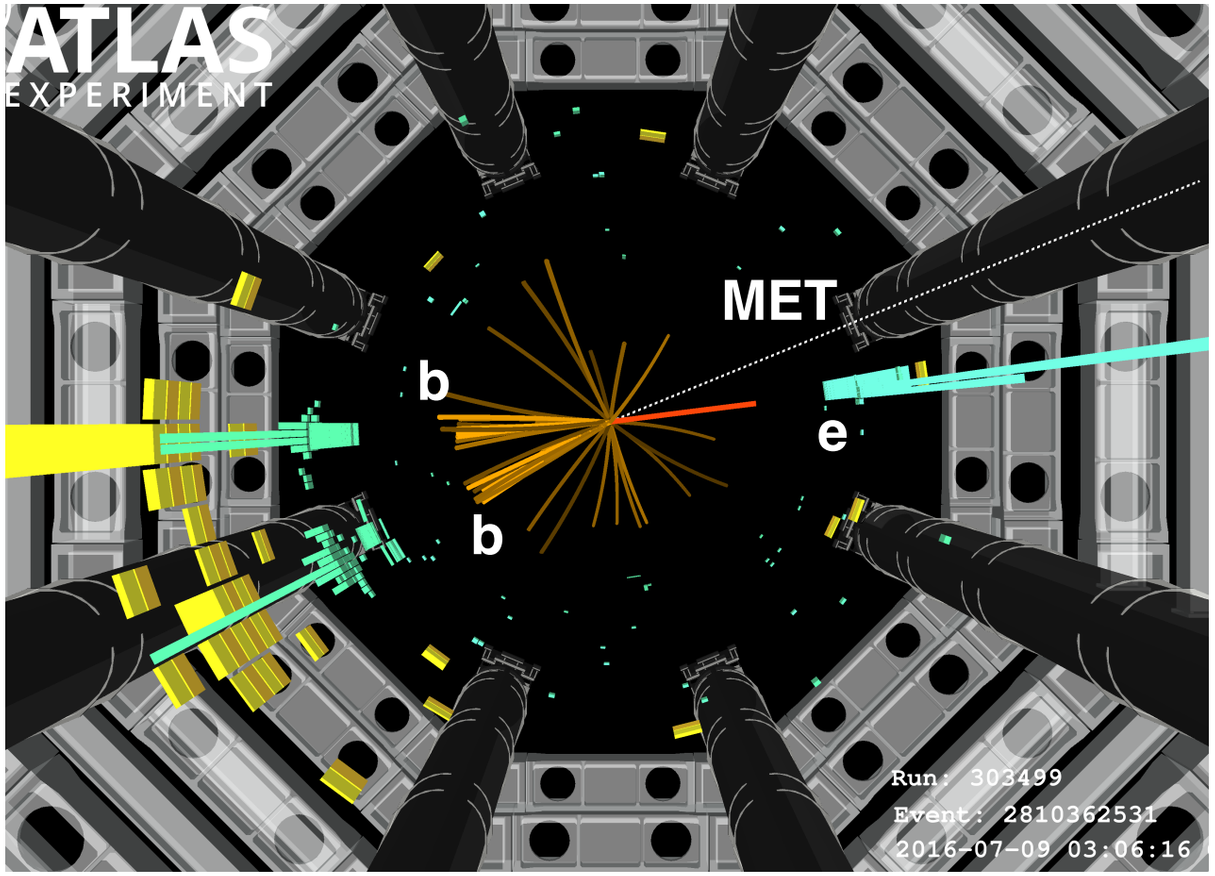


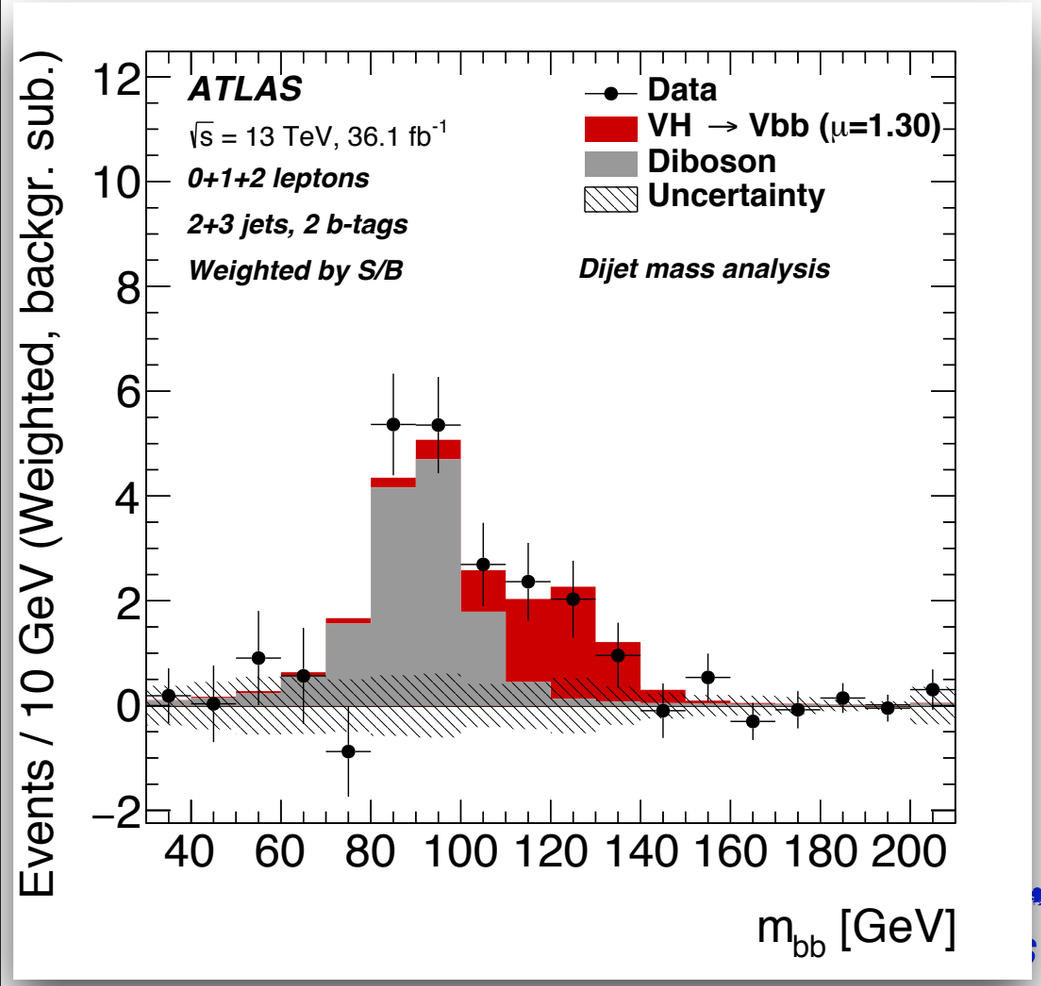
Higgs boson coupling to quarks: H→bb

arXiv:1708.03299

- ***VH associated production:***
  - leptons from W/Z used for triggering/background reduction





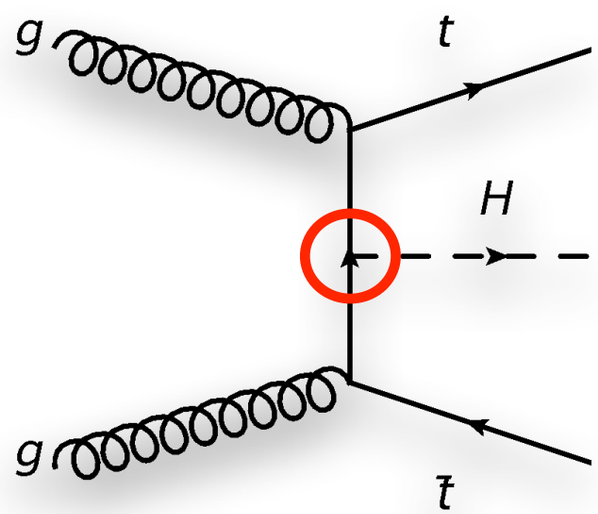


- *Run 1+Run 2:* ***3.6 (4.0) σ observed (expected)***

$$\frac{\sigma_{meas}}{\sigma_{SM}} = \mu_{VH\to bb} = 0.90\,^{+0.18}_{-0.18}(\text{stat.})\,^{+0.21}_{-0.19}(\text{sys.})$$

evidence of H→bb through VH associated production

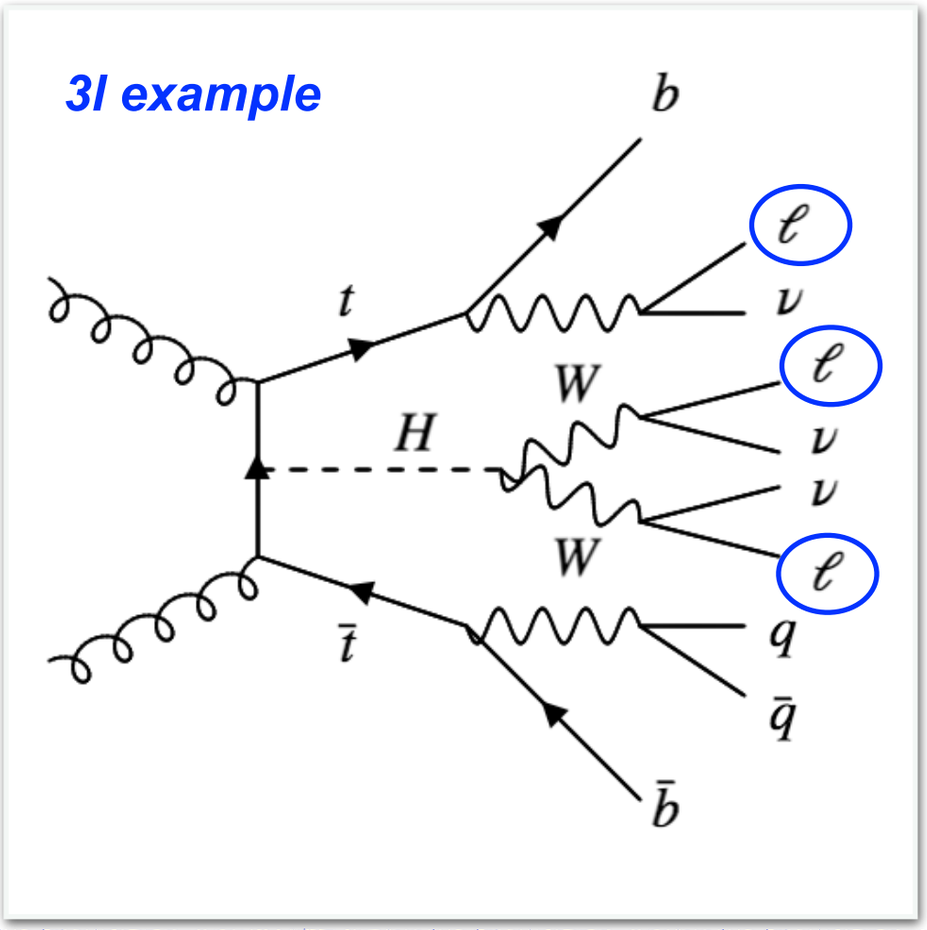
Higgs boson coupling to quarks: ttH



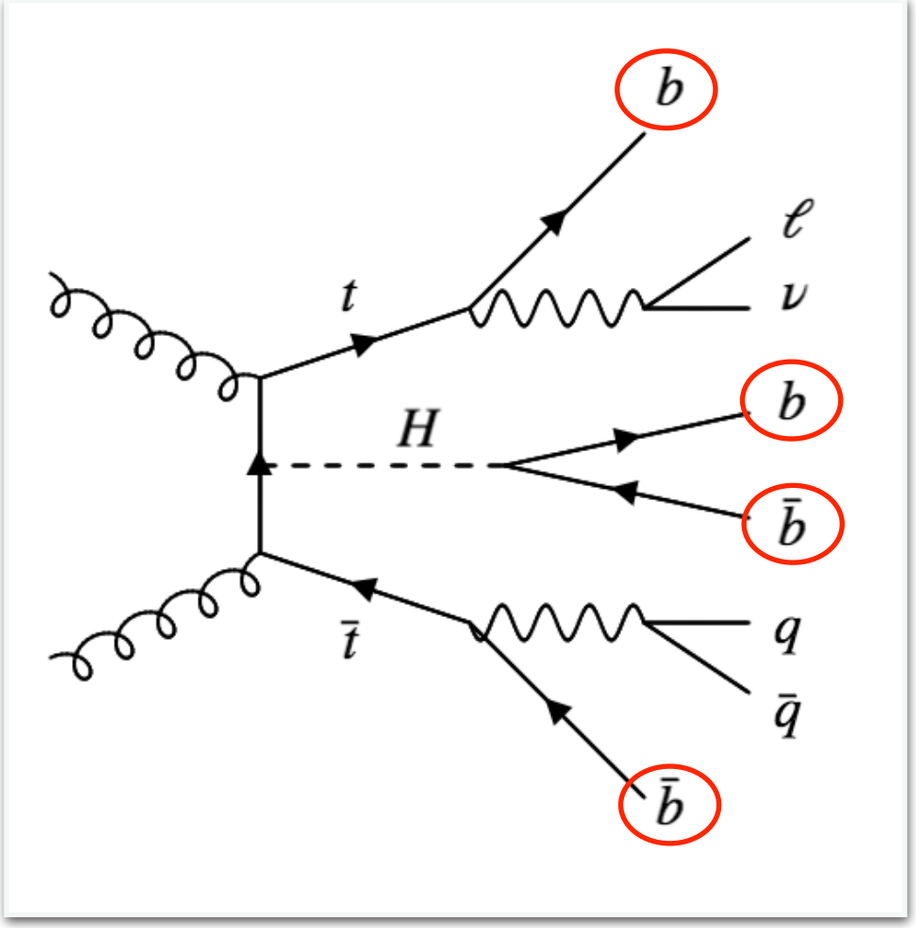
- ***ttH production***:
  - *direct access to top Yukawa coupling at tree level*
  - expected cross section: 500 fb
  - rich phenomenology: need to combine many signatures

H→WW, ττ, ZZ

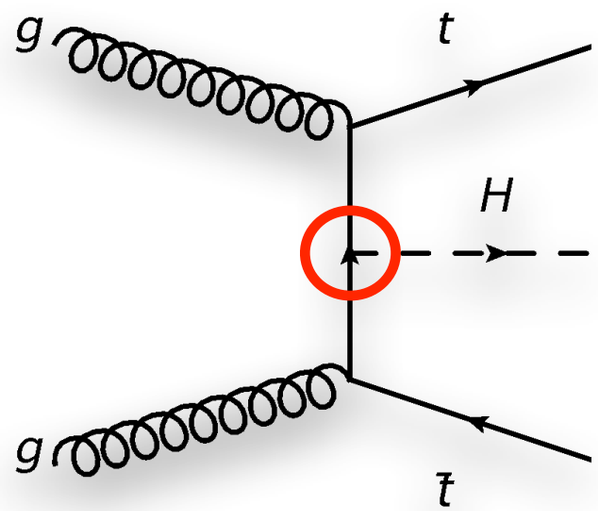
- *very crowded final states*
- *large backgrounds constrained from data*
- *multivariate classification techniques*



H→bb



Higgs boson coupling to quarks: ttH



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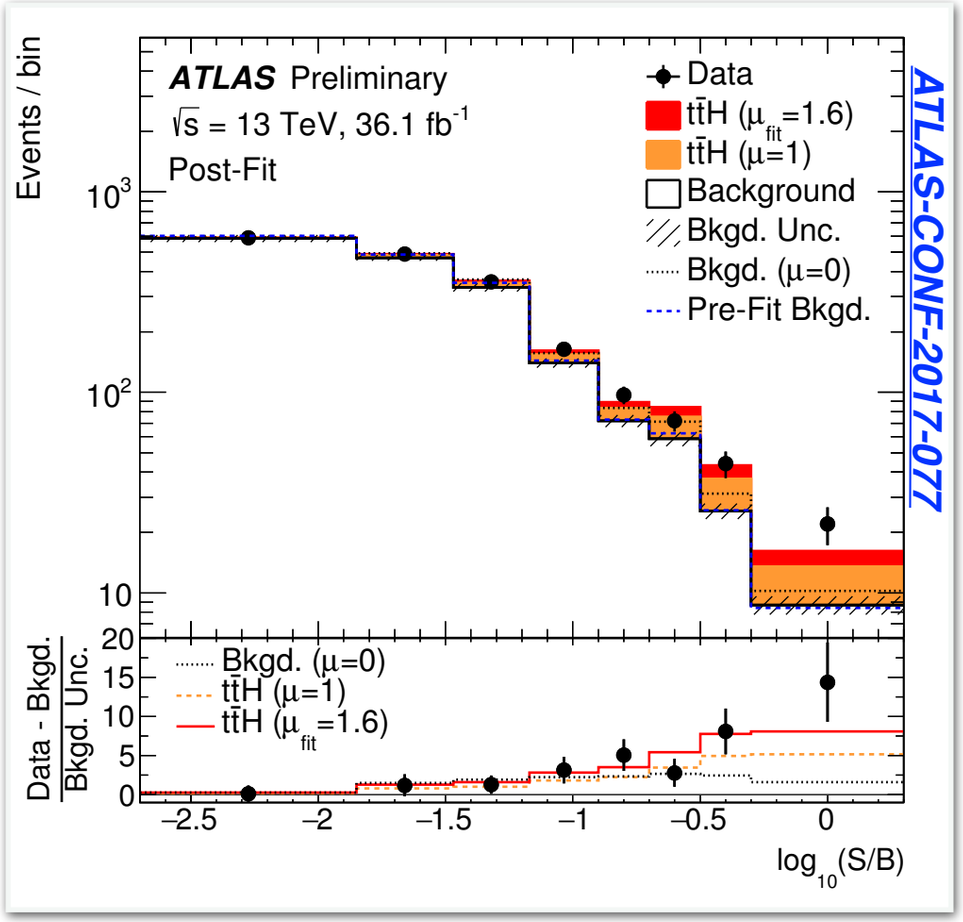
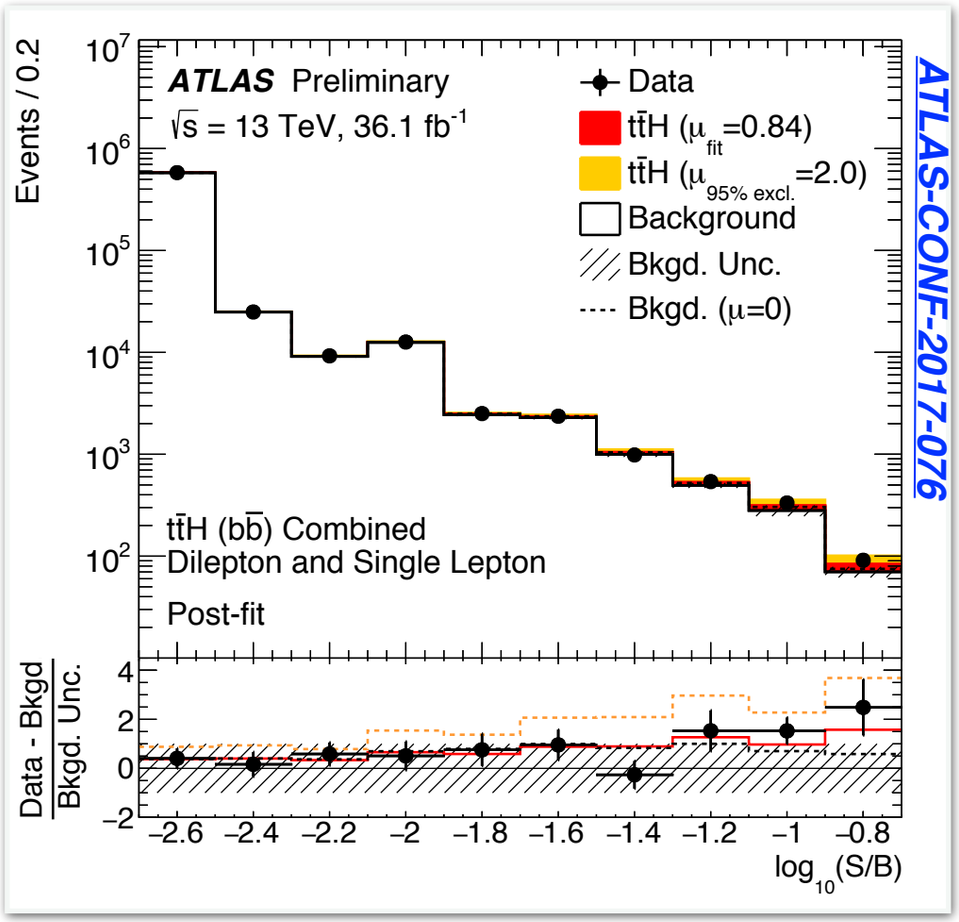
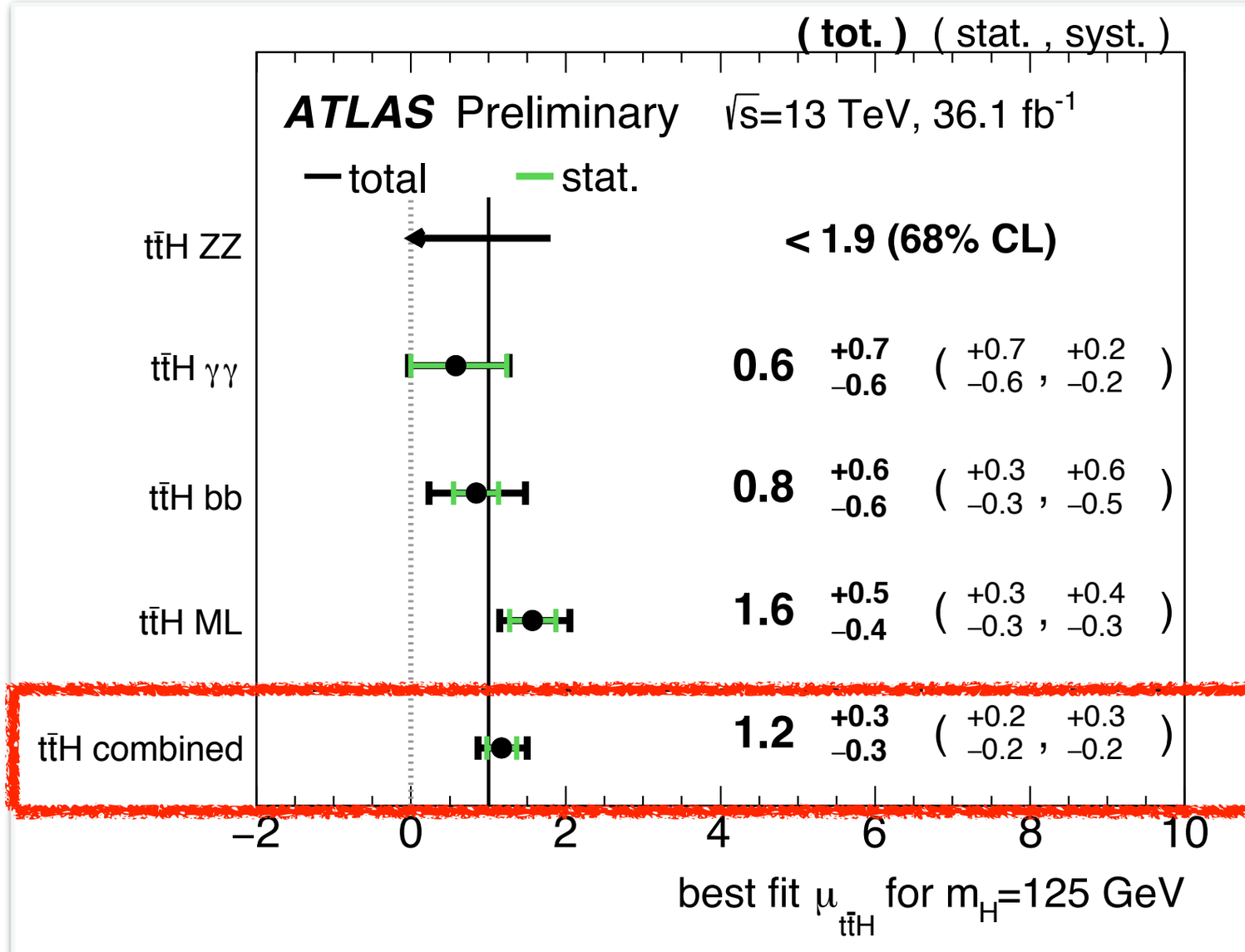


H→bb



ttH: combination

- Also including events targeting H→γγ and H→ZZ→4l:
  - *very high S/B but still low number of expected events*



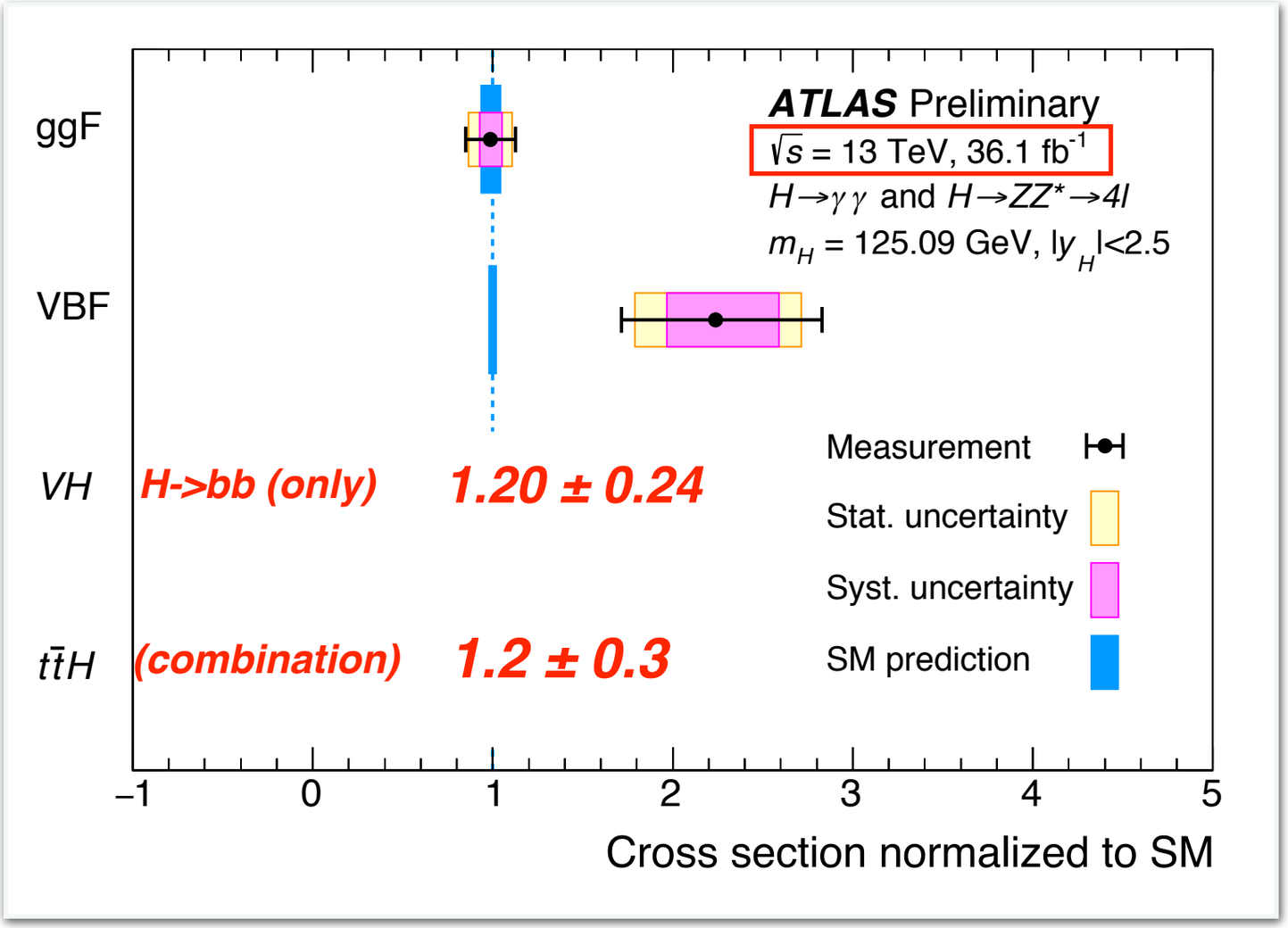
	significance obs.	significance exp.
tt̄H ZZ		
tt̄H γγ	1.7σ	0.9σ
tt̄H bb	1.6σ	1.4σ
tt̄H ML	4.1σ	2.8σ
tt̄H combined	4.2σ	3.8σ

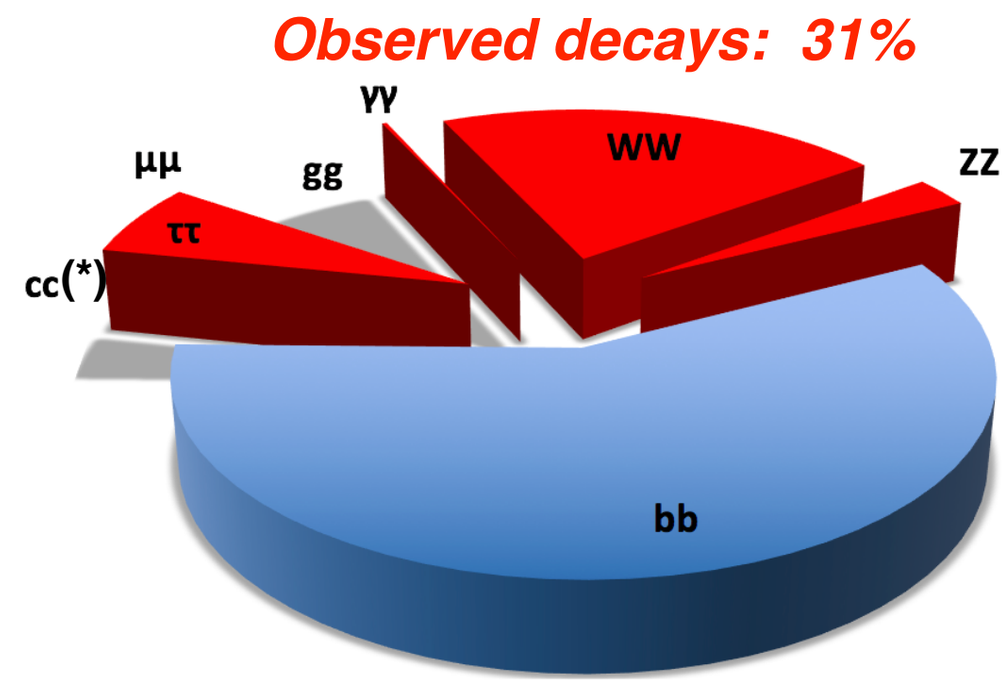
evidence for ttH production

one of the rarest process measured at the LHC

$$\sigma_{\text{meas}}(t\bar{t}H) = 590\,^{+160}_{-150}\ \text{fb}$$

Snapshot of the Higgs boson landscape: Run 1+Run 2





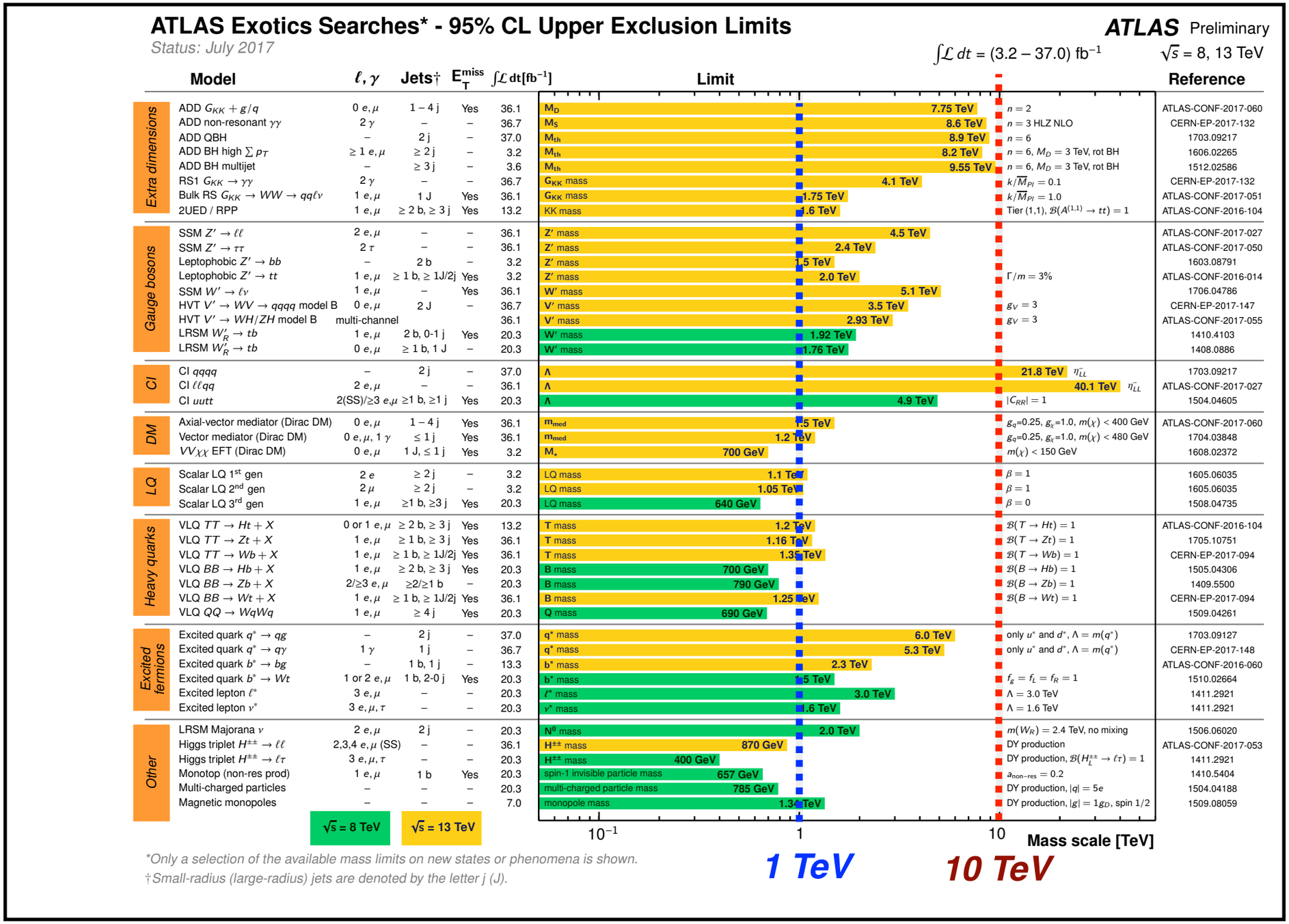
- ***Additional statistics is needed to***:
  - *improve the precision of the existing measurements*
  - *assess rare production/decay modes*
  - *expand differential cross section measurements*

(*) First direct limits on H→cc
(ATLAS-CONF-2017-078)
$\sigma_{ZH \times Br(H\to cc\ell\ell)} < 2.7$ **pb**

Searches for physics beyond the SM

- Higher √s and luminosity have greatly increased our reach for new physics up to high masses

Exotics



Searches for physics beyond the SM

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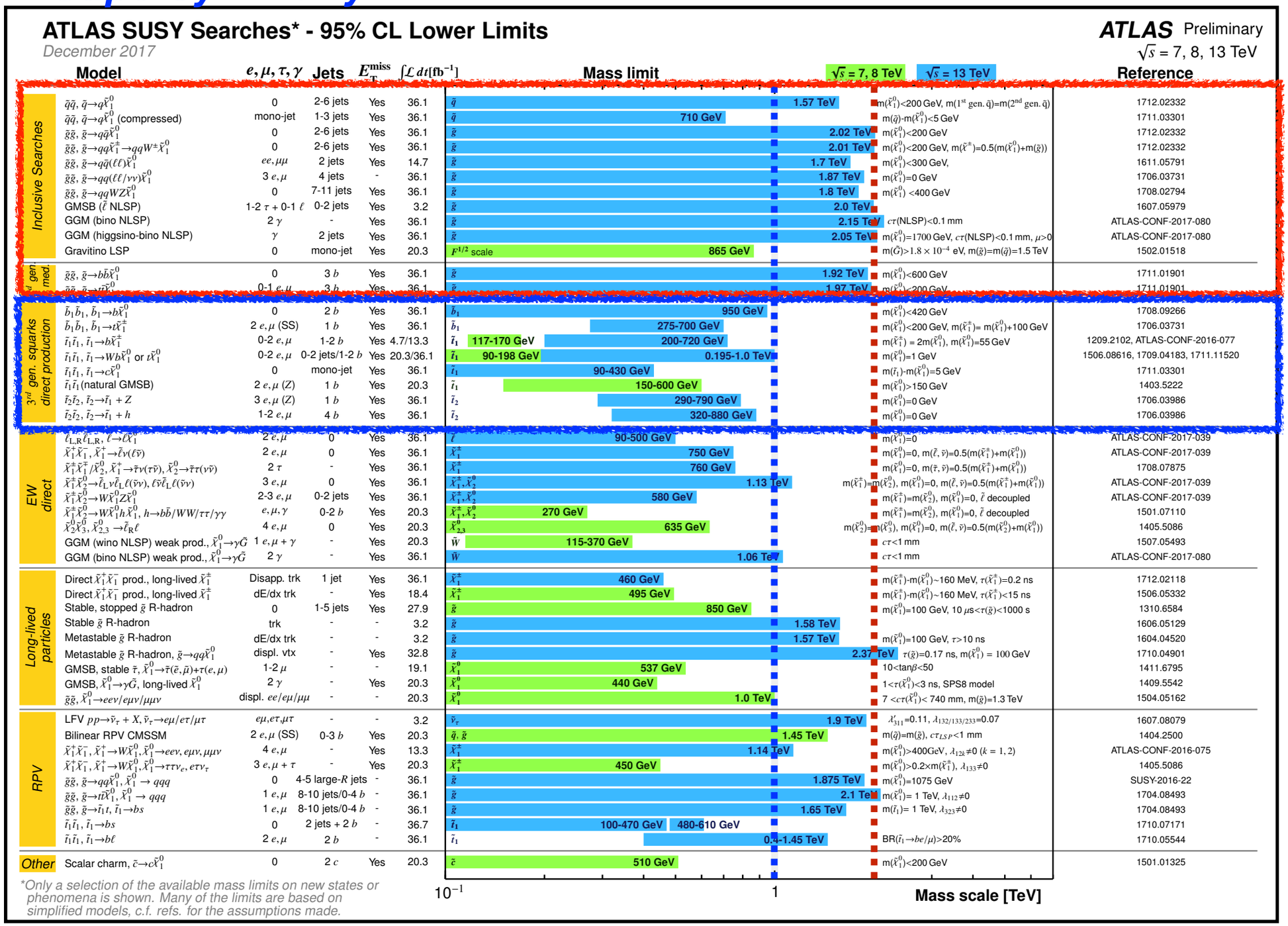
Supersymmetry



- ***Gluino*** mass limit pushed up to 2 TeV

- ***Stop*** mass limit reaching 1 TeV

1 TeV ***2 TeV***

Searches for physics beyond the SM

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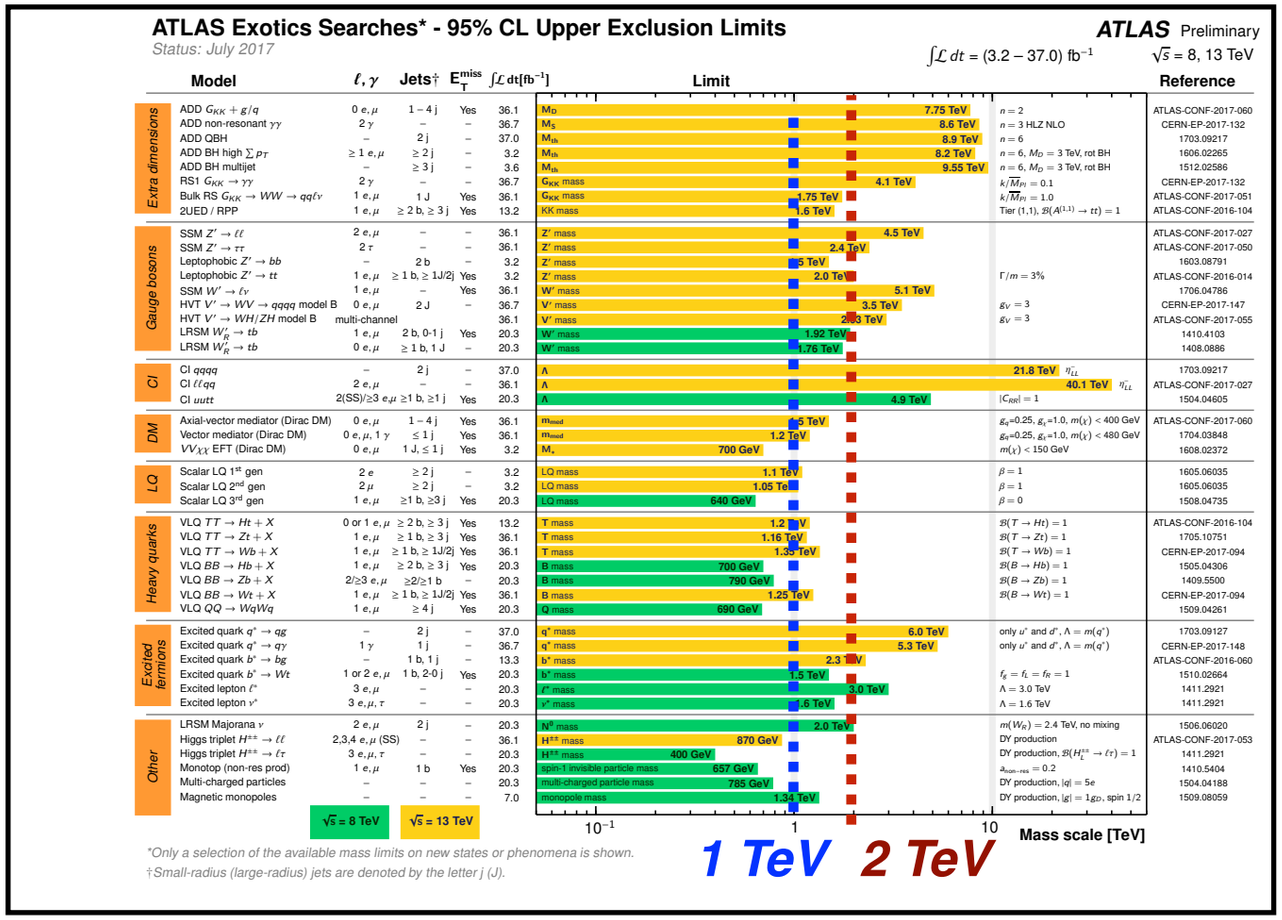
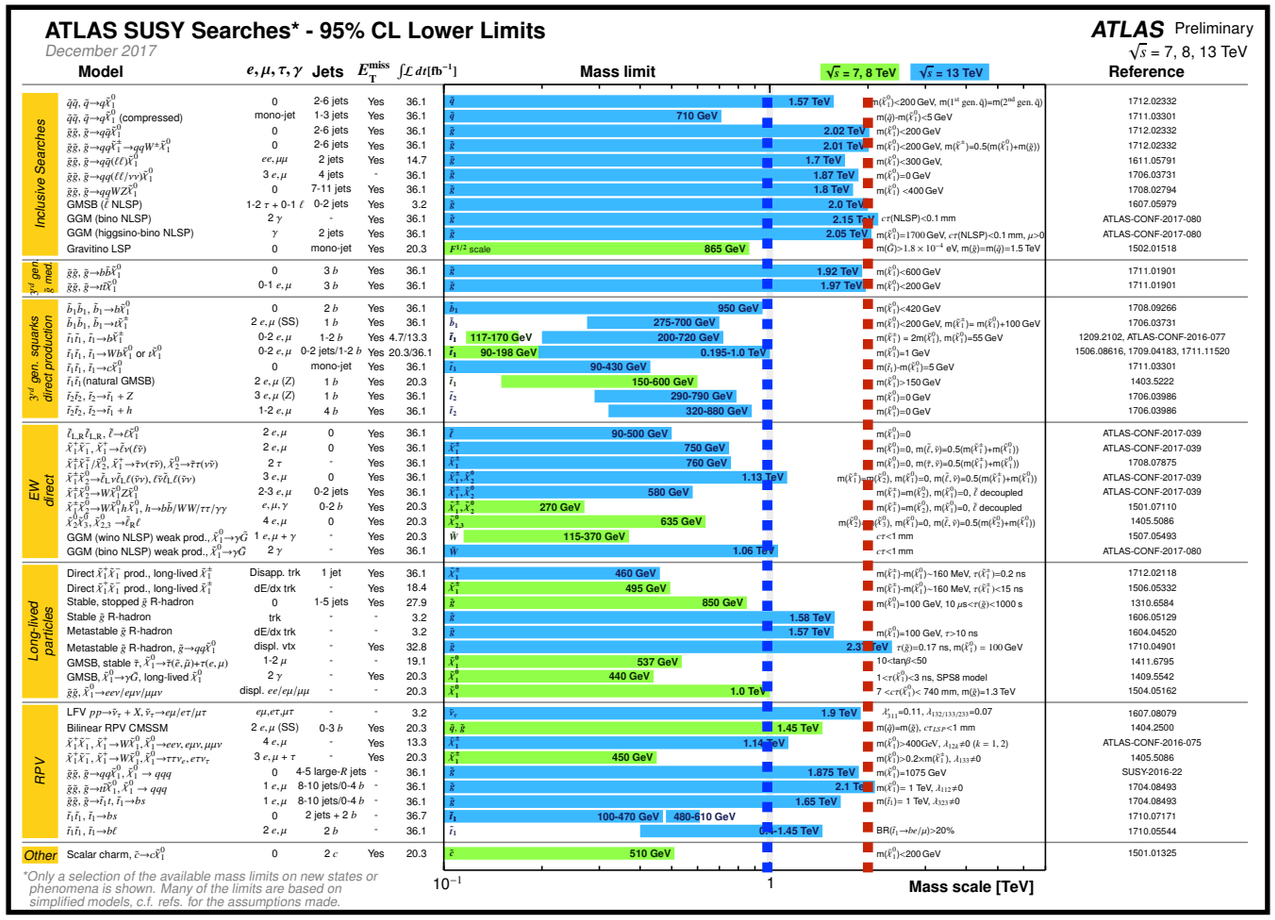
Exotics



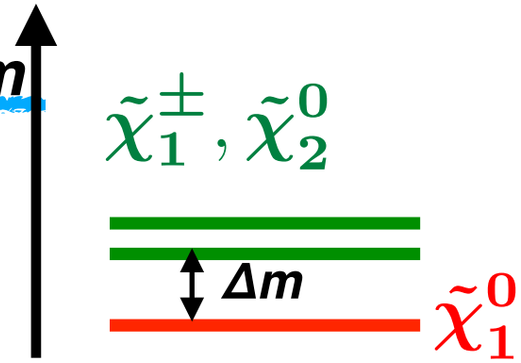
Supersymmetry



- Continuously developing new analysis techniques/exploiting more complete information:
  - accessing difficult corners of phase space
  - increasing coverage of new models

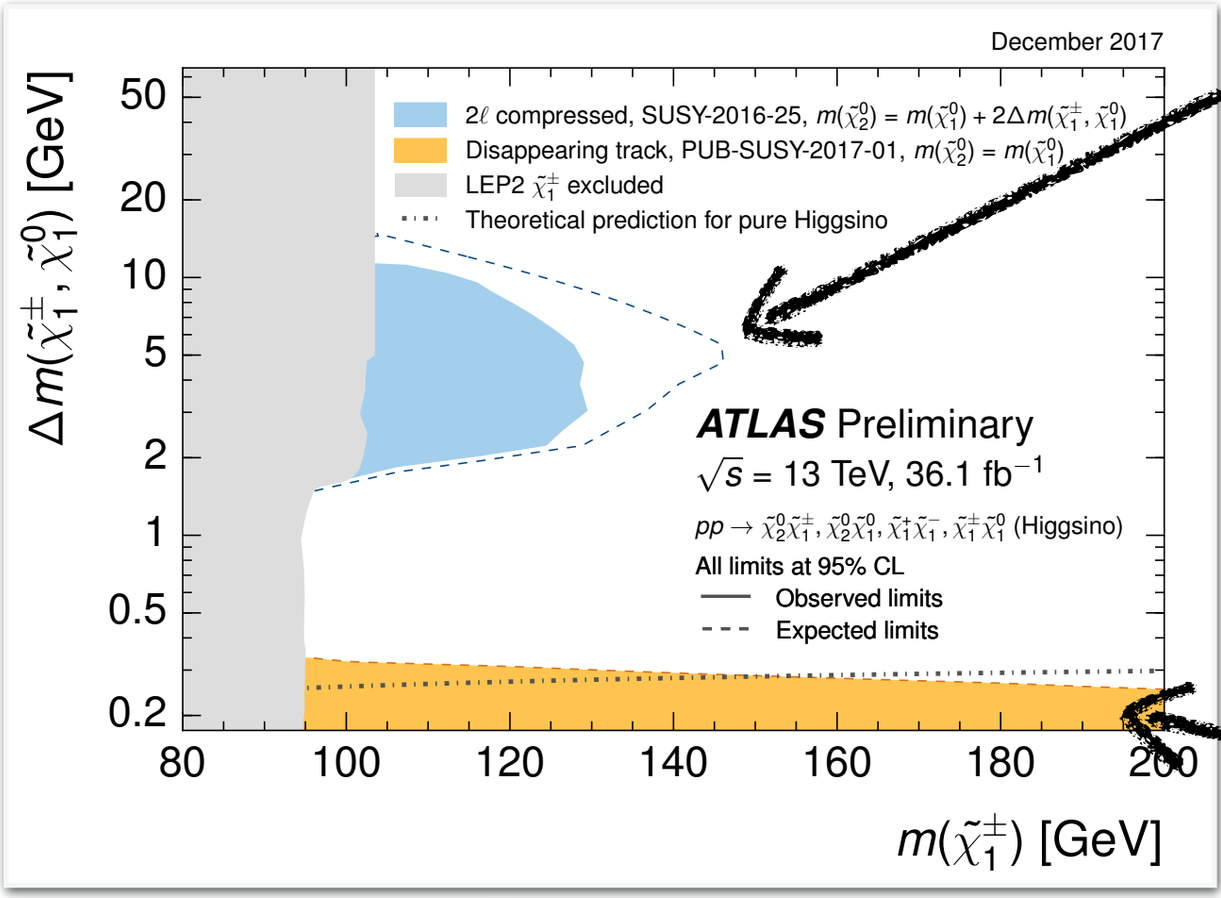
leave no stones unturned

Electroweak Supersymmetry

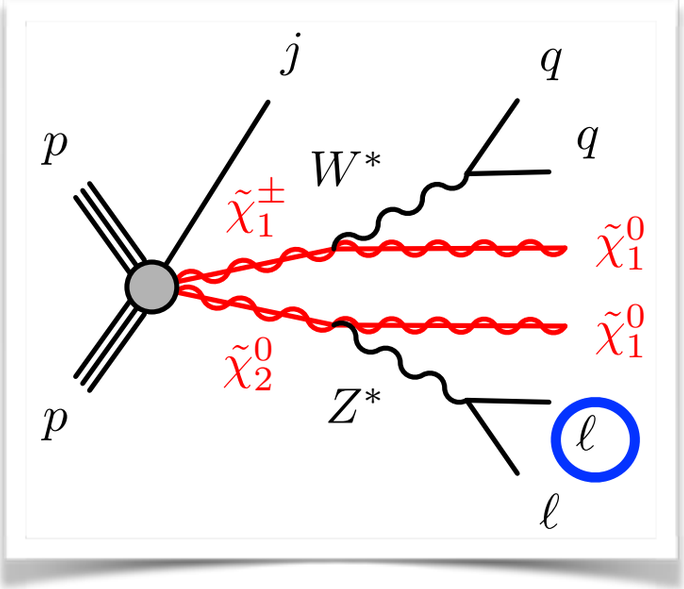


- (compressed) ***electroweak SUSY*** is a very elusive sector

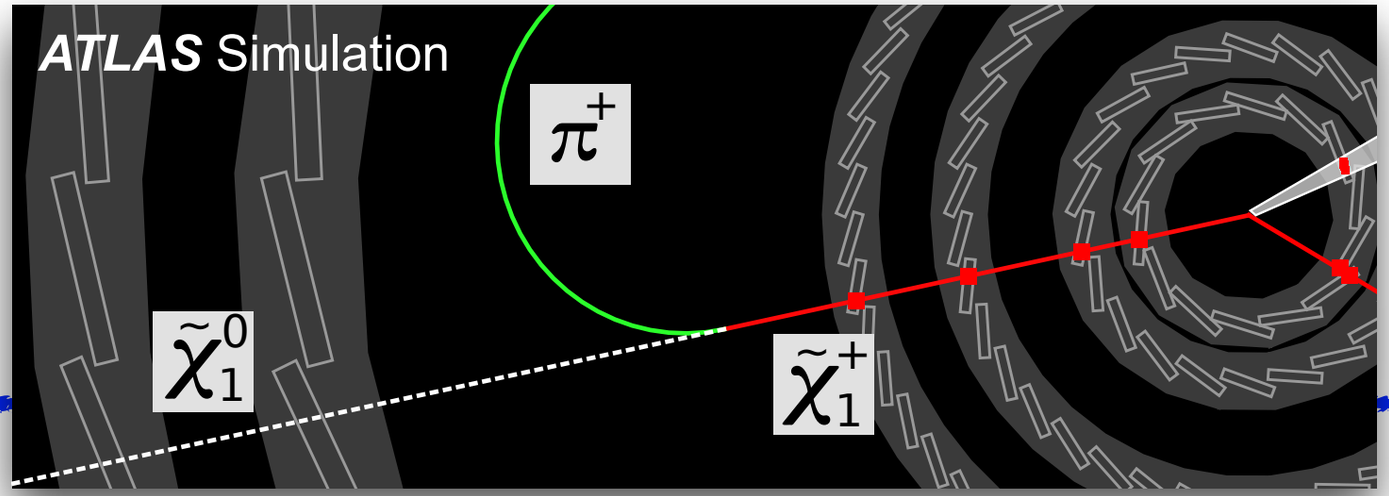
- ***First sensitivity to Higgsino beyond LEP***



- few GeV-level splitting accessible through ***soft leptons*** (down to 4 GeV)



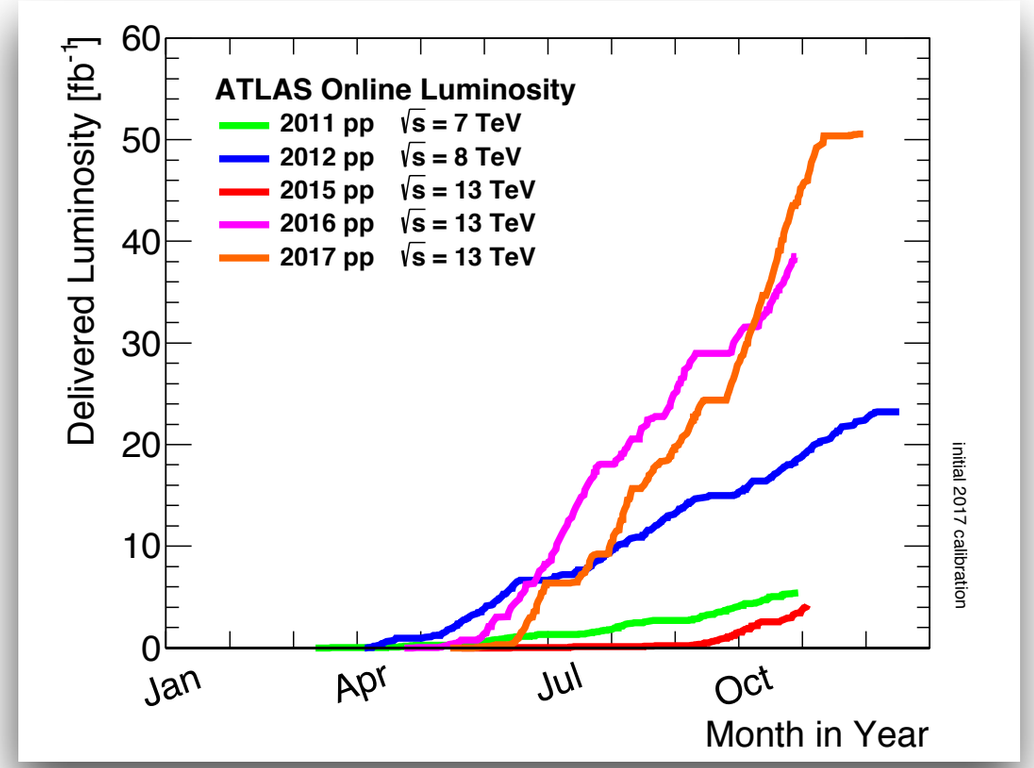
- O(100 MeV) splitting produces long-lived charginos: accessible through ***disappearing tracks***

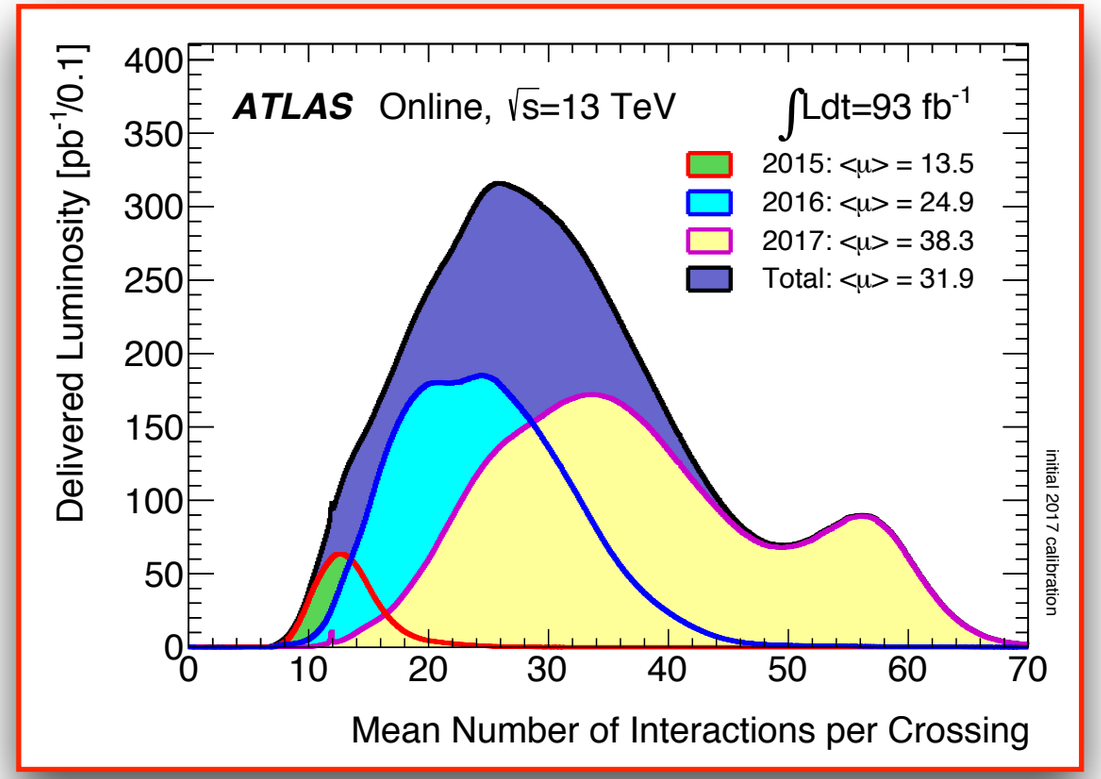


Another great year for LHC

A big thank you to the CERN accelerator and support teams for the excellent performance

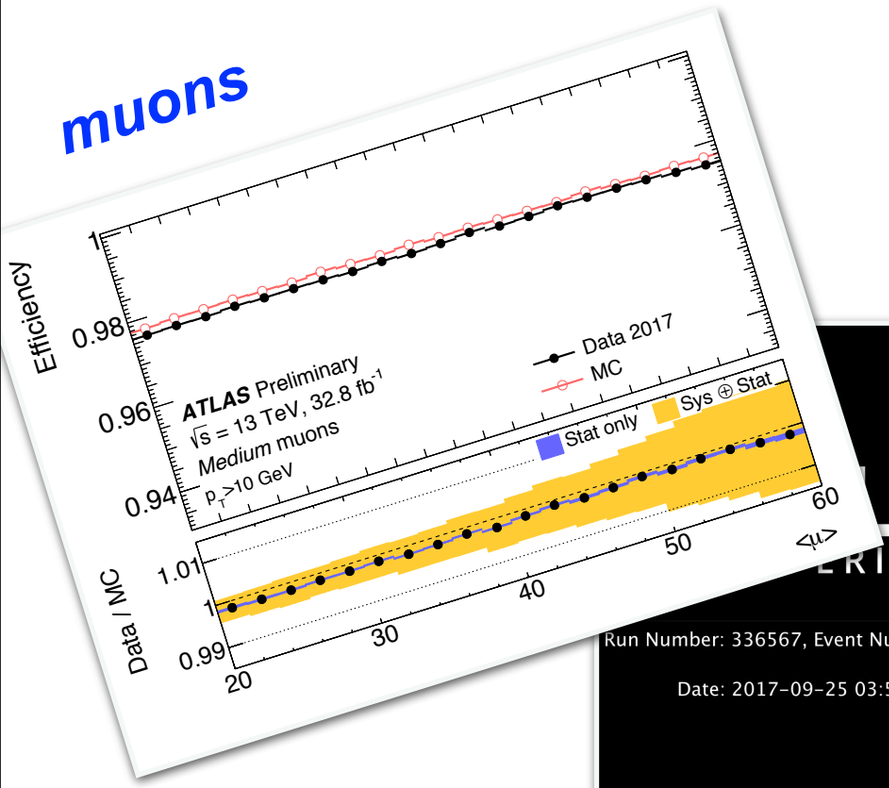
- Additional 50 fb^{-1} of pp collisions @ 13 TeV
- low pileup runs @ 5 and 13 TeV

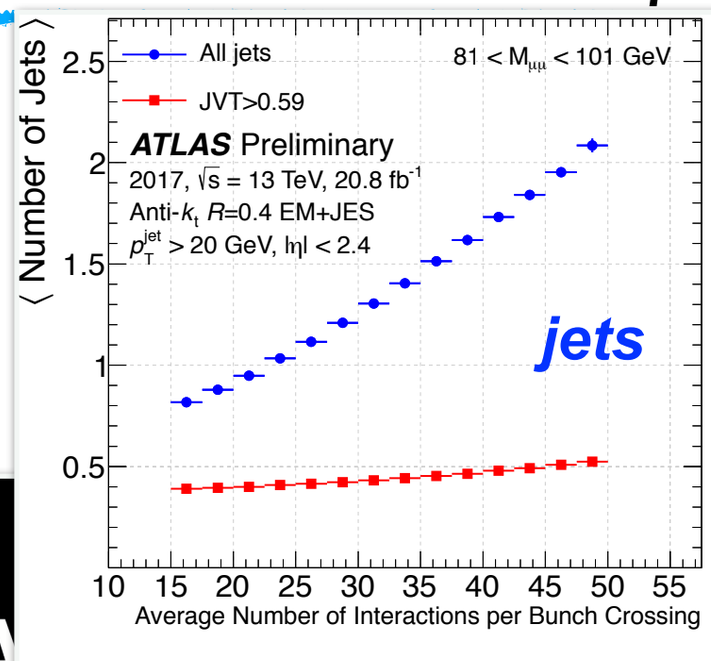




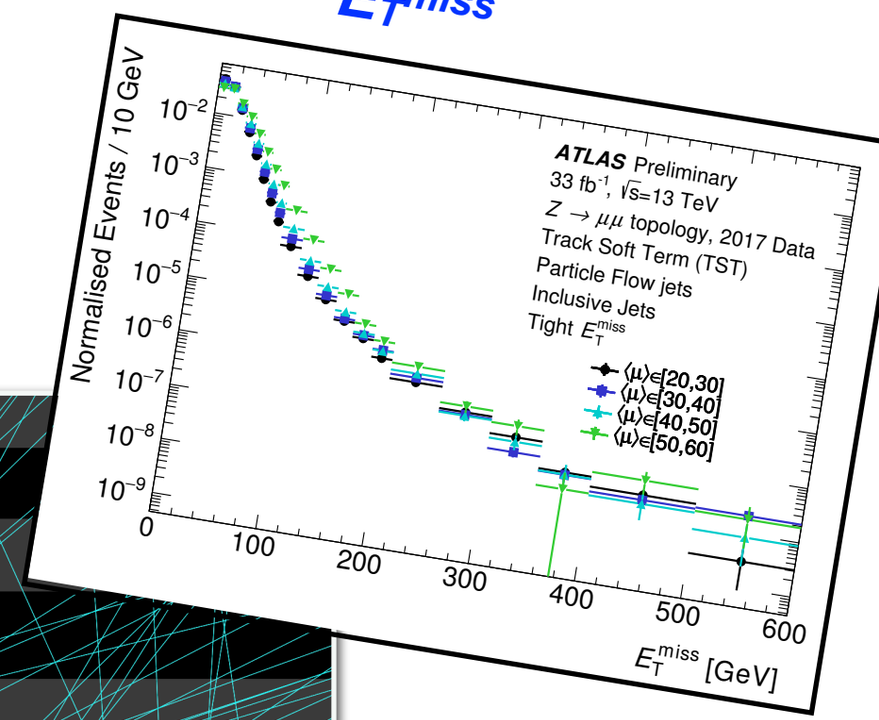
Performance with 2017 pileup

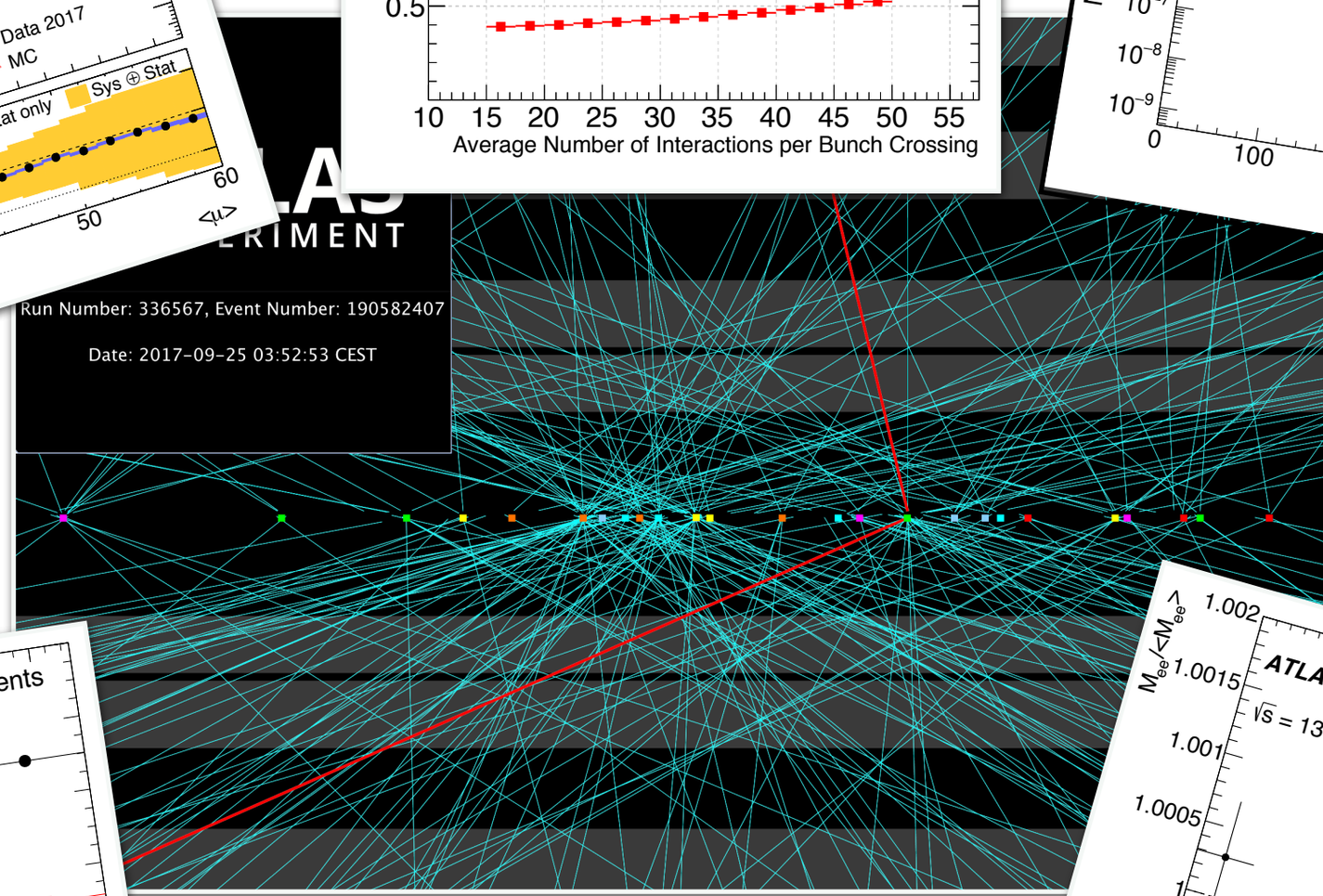
muons



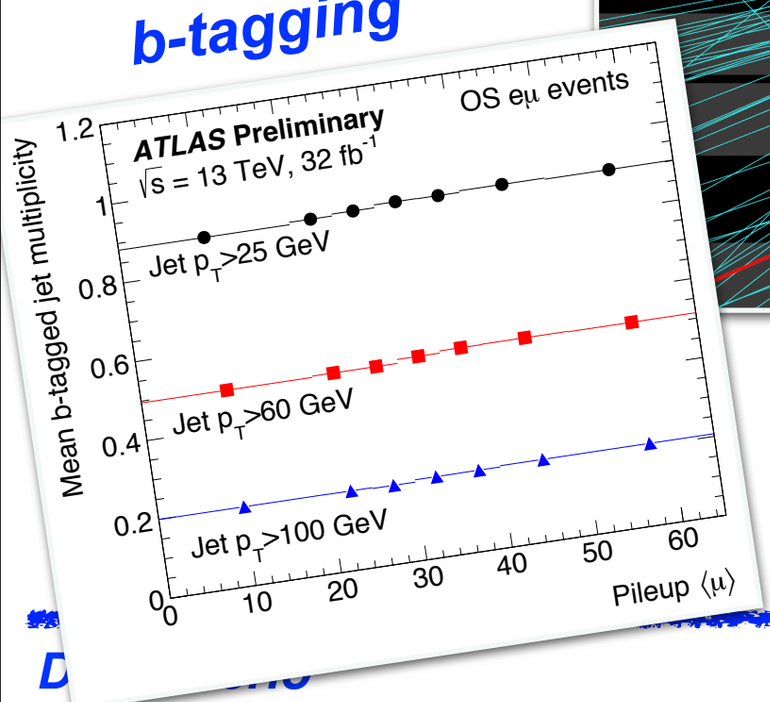


E_T^{miss}

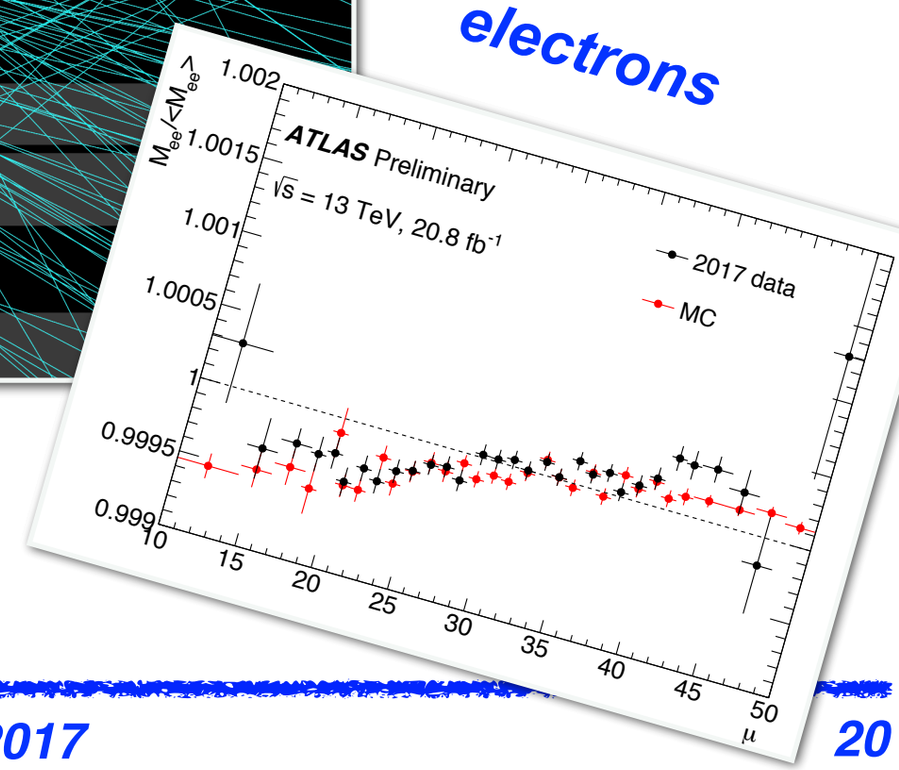




b-tagging



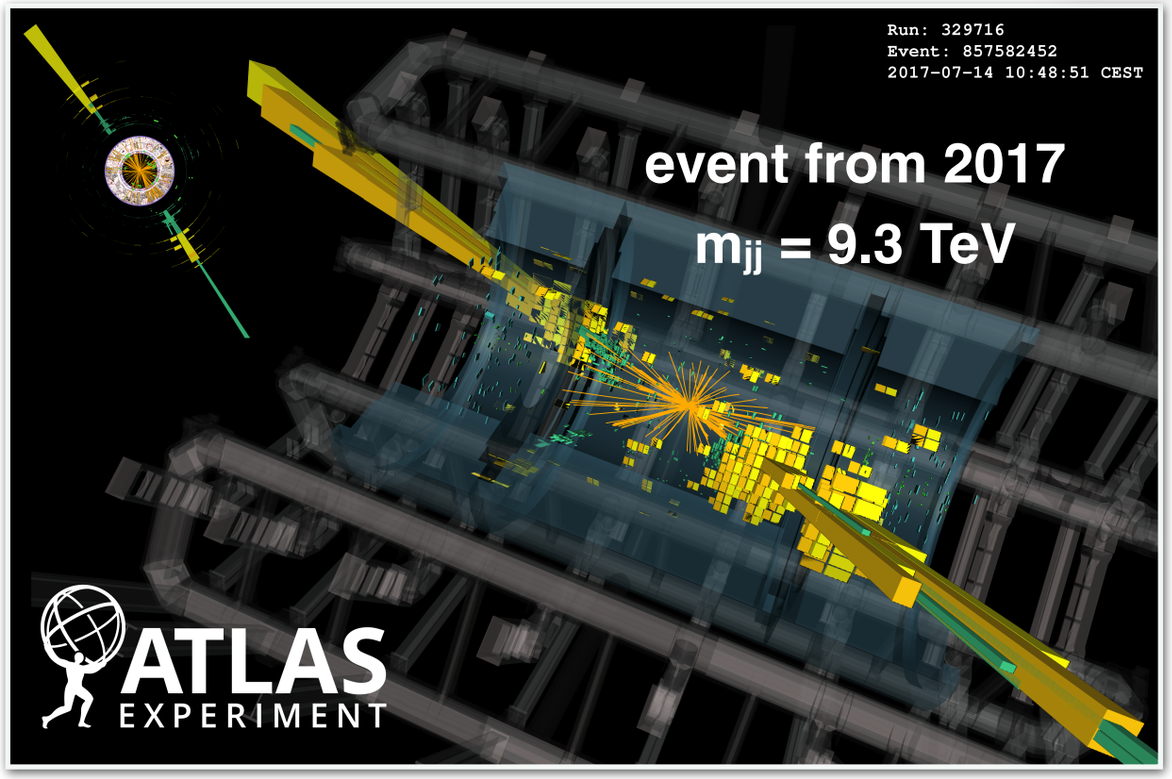
electrons



Z→μμ event with μ=50

Looking ahead

- *This was only a small selection of the full set of ATLAS results:*
  - 46 results released on 2015/16 data
  - ~700 from pp and heavy ions since 2010



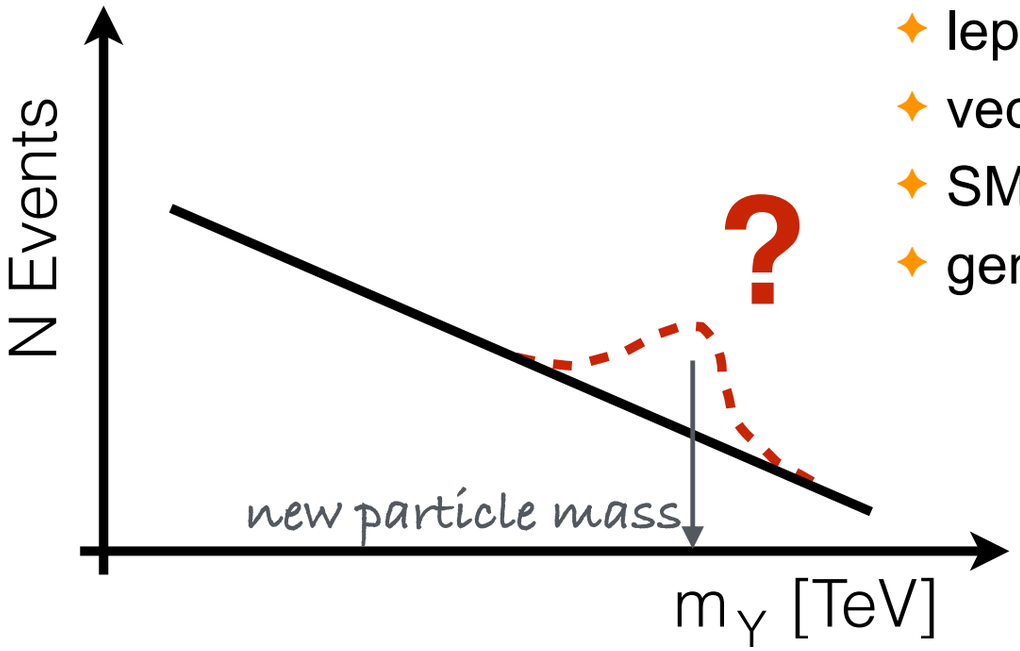
- *New 2017 data on tape is larger than what we have analysed so far at 13 TeV*
- *Even more data to come in 2018 for both pp and heavy ion collisions*

Thank you for your attention

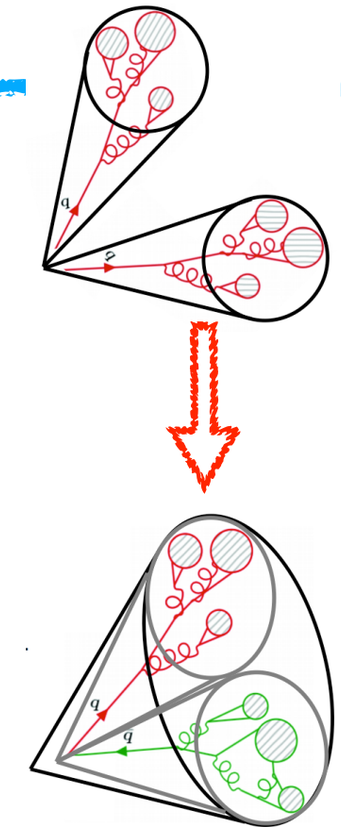
BackUp

Exotics: resonances

- ***Comprehensive searches for Y→XZ*** :
  - leptons, photons, jets
  - vector boson
  - SM-like Higgs boson to bb
  - generic state decaying into qq

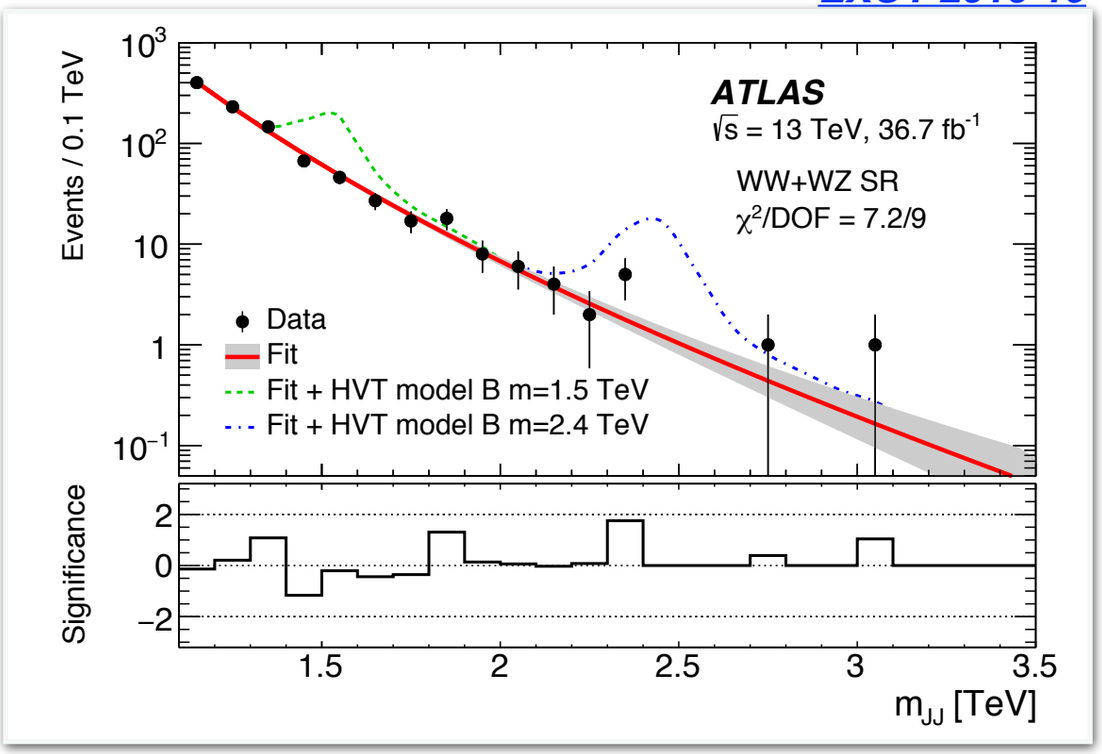


- ***Boosted hadronic final states (V,H,X) bridge into the multi TeV regime***



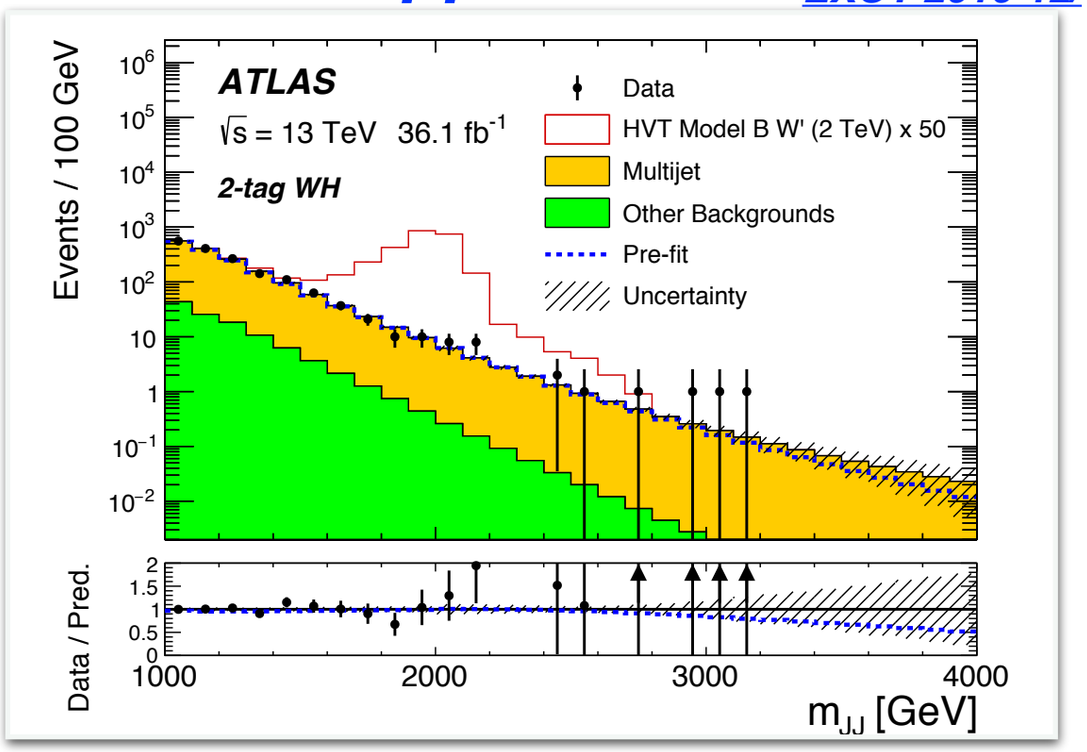
VV→qqqq→JJ

EXOT-2016-19



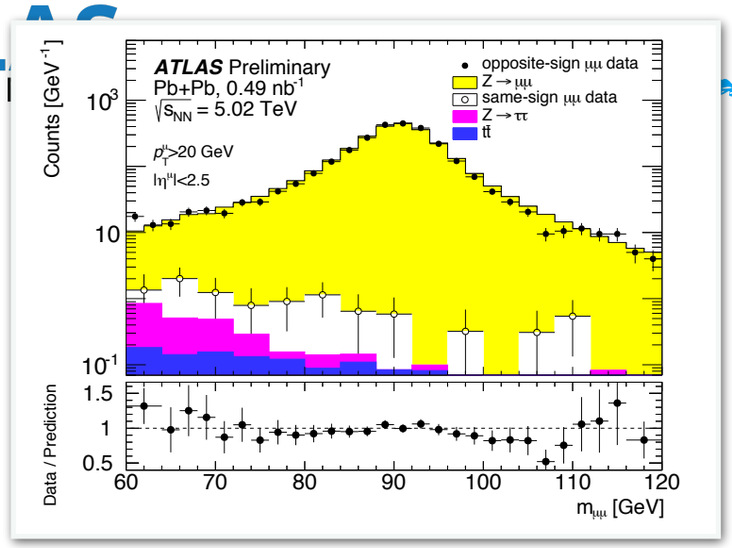
Vh→qqbb→JJb

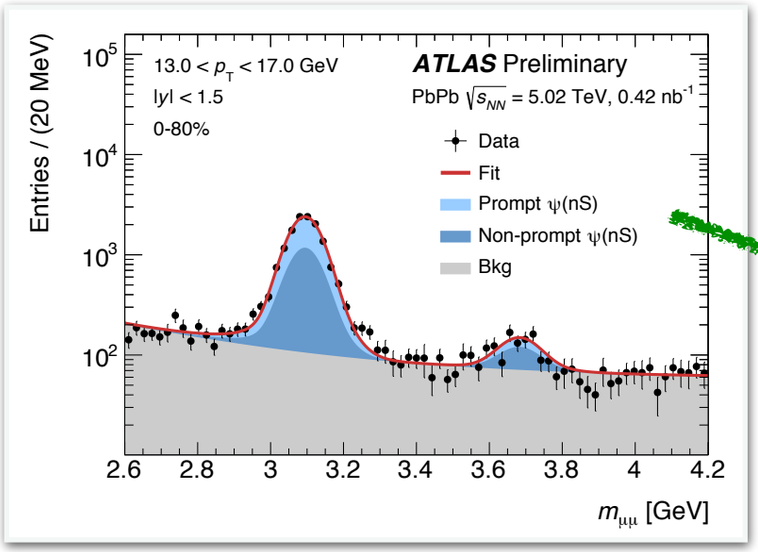
EXOT-2016-12/

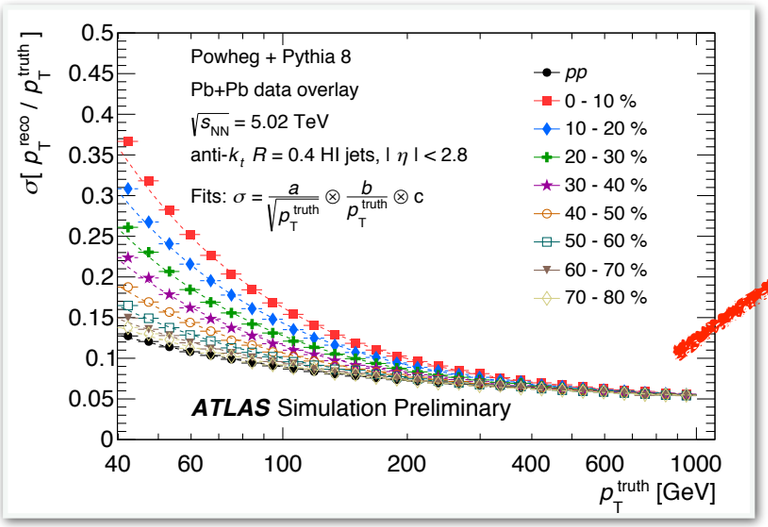


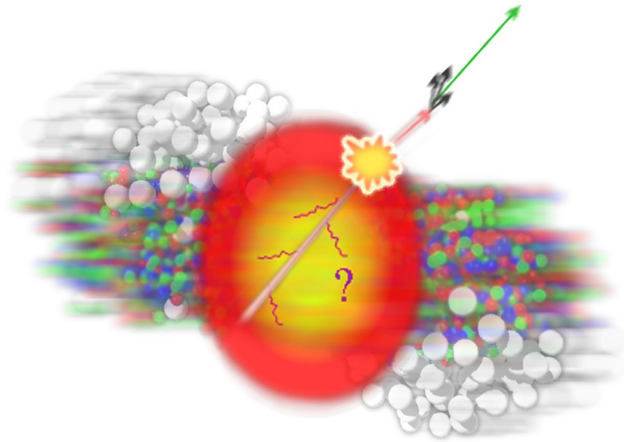
Heavy Ions

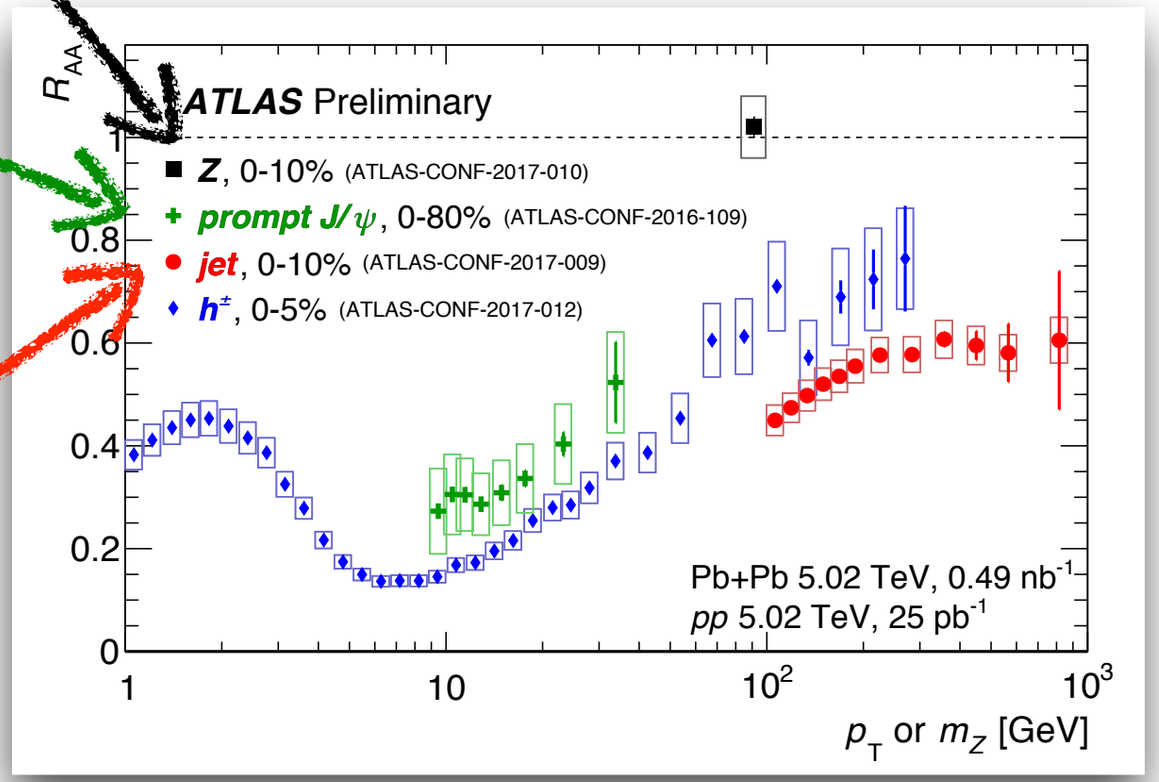
- … from ***2015 PbPb*** run: measuring "quenching" in Heavy Ions medium for different probes





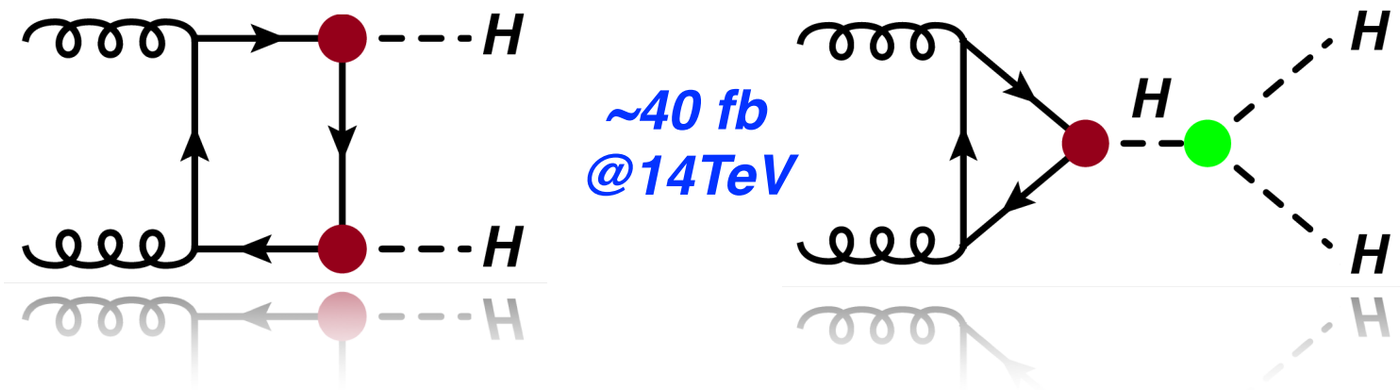






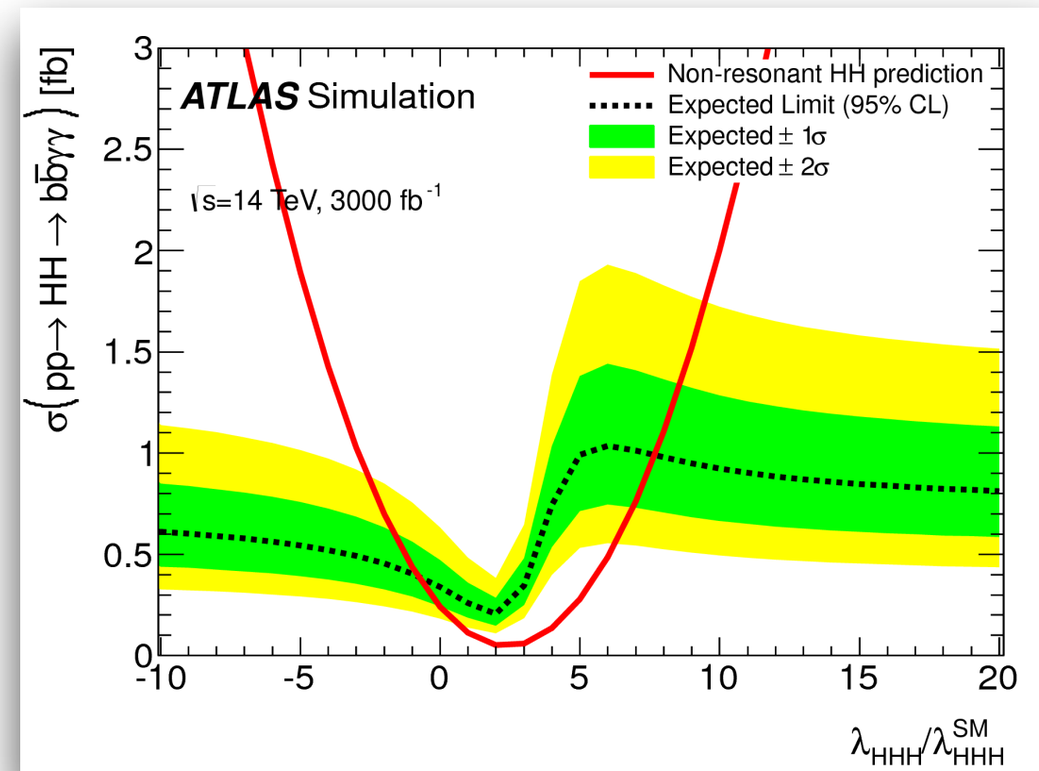
Looking at 3ab^{-1}

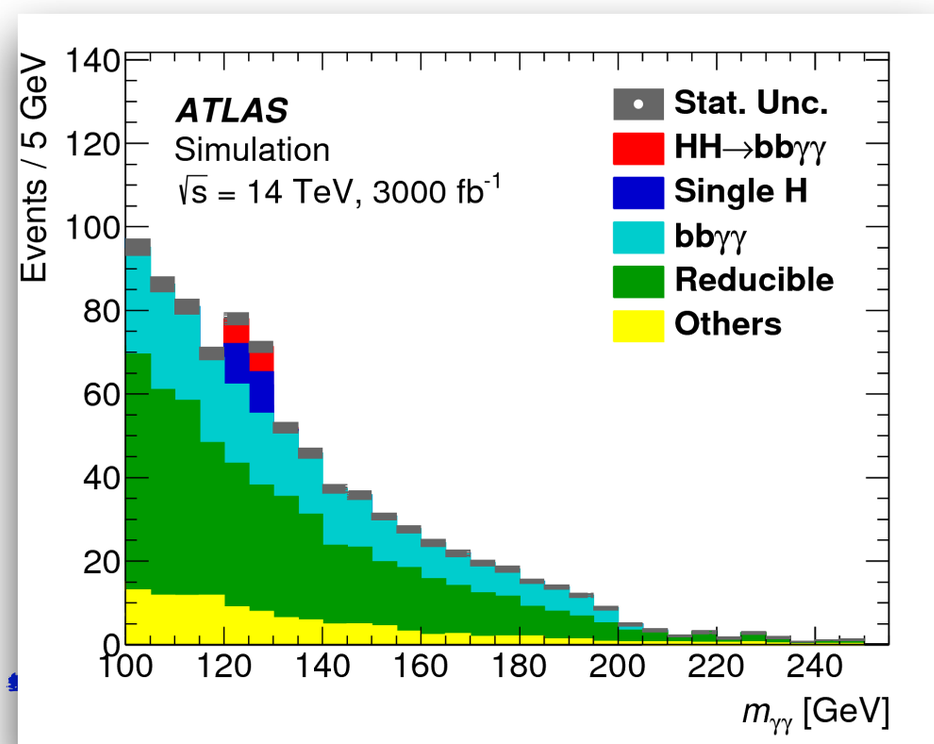
- Looking at Di-Higgs production as a window for Higgs self coupling



best Run2 result:
HH->bbbb (13 fb^{-1})
σ/σ_{SM} <29 @95%CL

- ***HH->bb$\gamma\gamma$*** is the golden channel:
  - Br: 0.1% but very striking signal
  - better tracker: improved b-tagging / γ reconstruction
  - better calorimeter: improved $\gamma\gamma$ mass resolution

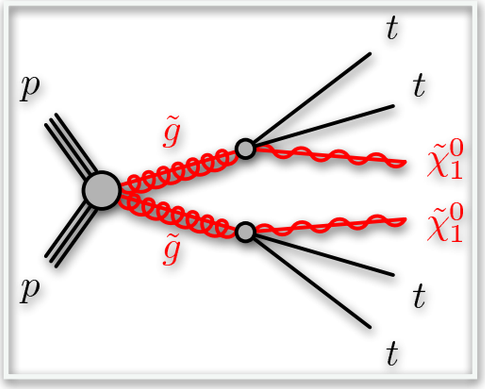


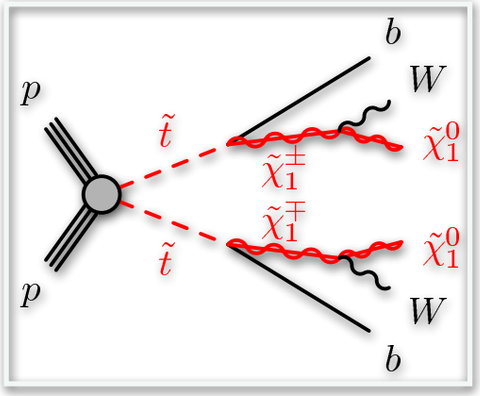


1 sigma expected for SM HH

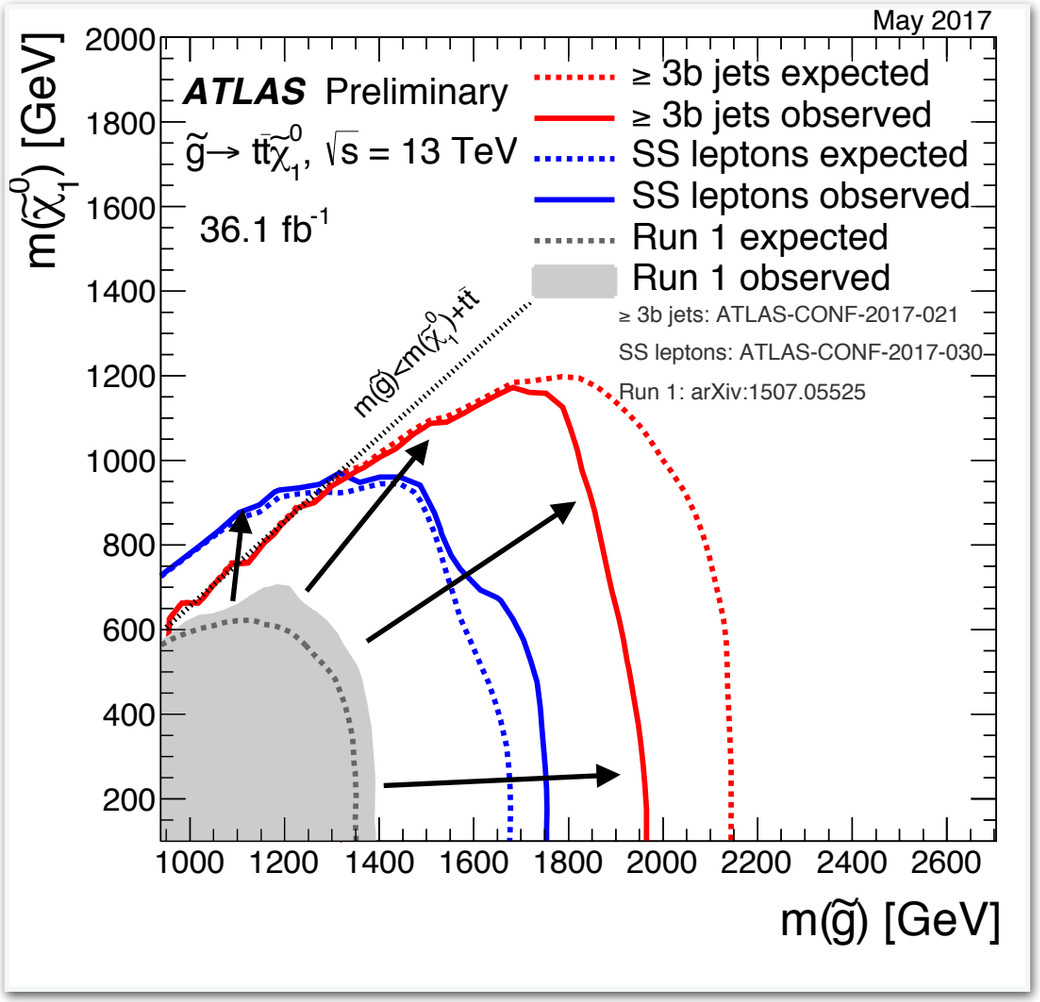
$-0.9 < \lambda/\lambda_{SM} < 7.7$

SUSY

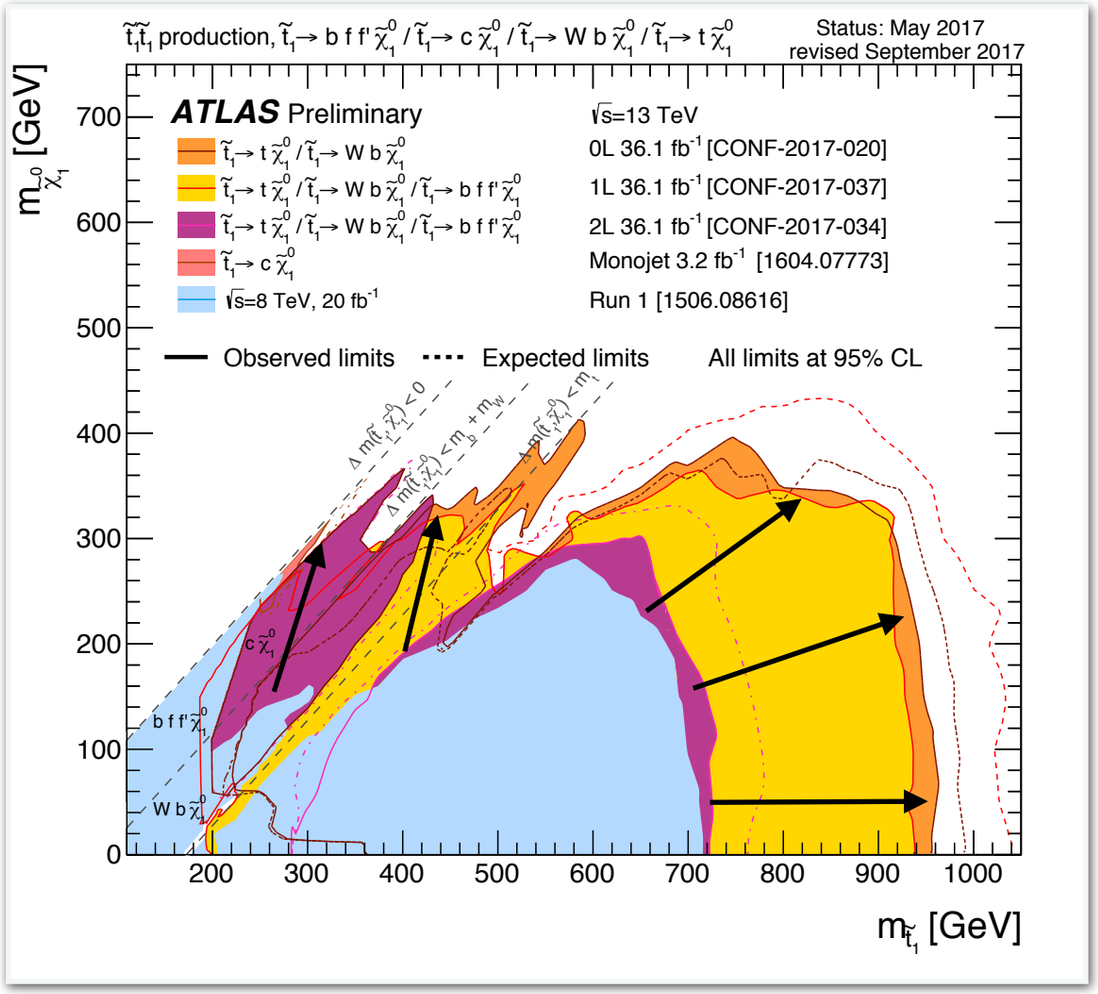




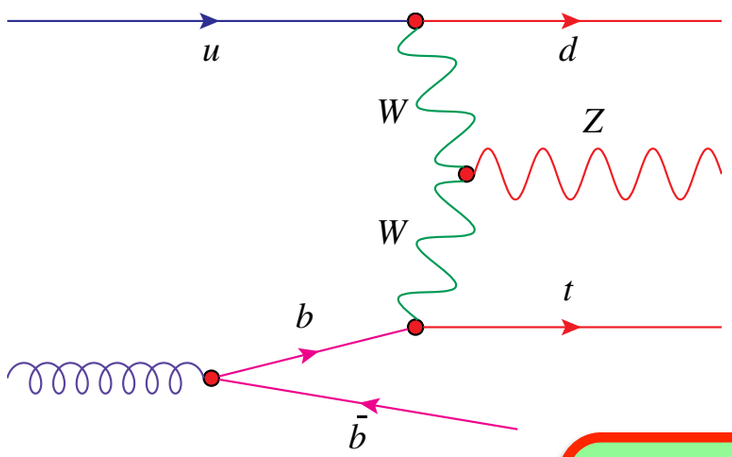
- ***Gluino*** mass limit pushed well into the TeV regime



- ***Stop*** mass limit approaching 1TeV: challenging naturalness



The top sector: very rare process



- ***tZ associated production***:
  - *3 lepton final state*
  - *1 Z pair, 2 jets, 1 b-tag jet*
  - *multivariate discriminant*

σ_{tqZ} = 600 ± 170(stat.)±140(syst.) fb

σ_{tqZ} (SM) = 800 ± 60 fb

4.2 s.d. evidence !!!