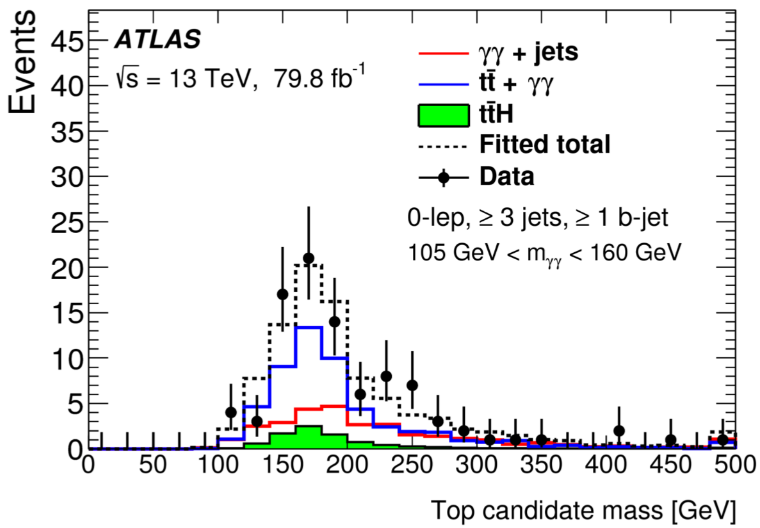
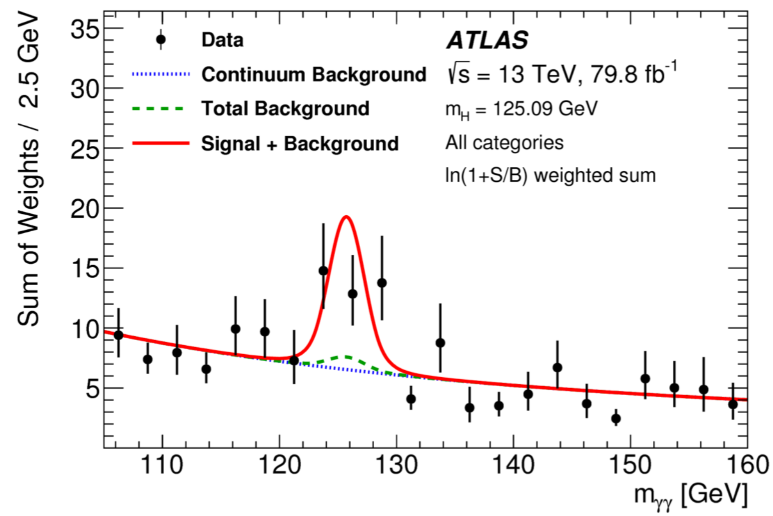
ATLAS ttH measurements in H→γγ at √s= 13 TeV





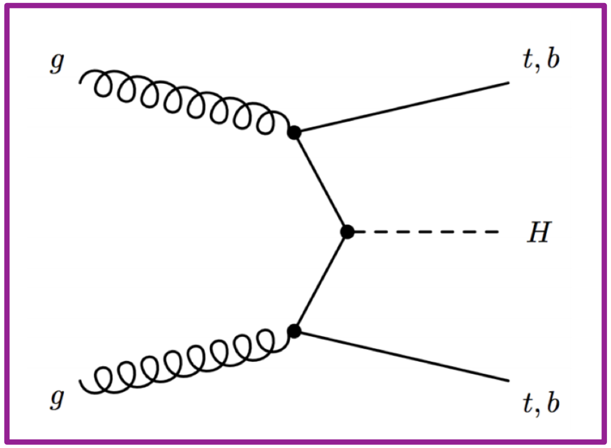
Jennet Dickinson

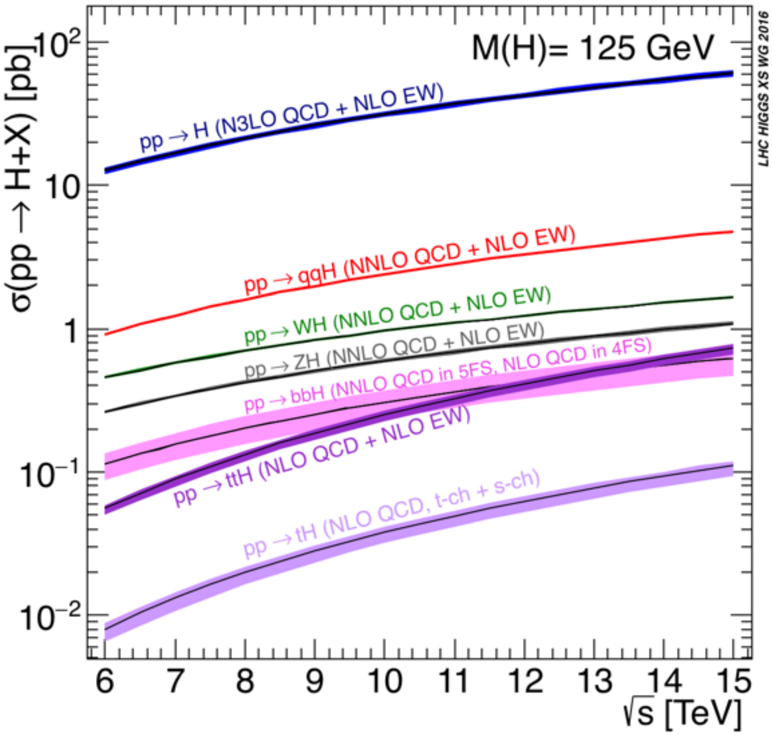
USLUA Lightning Round

10/26/2018

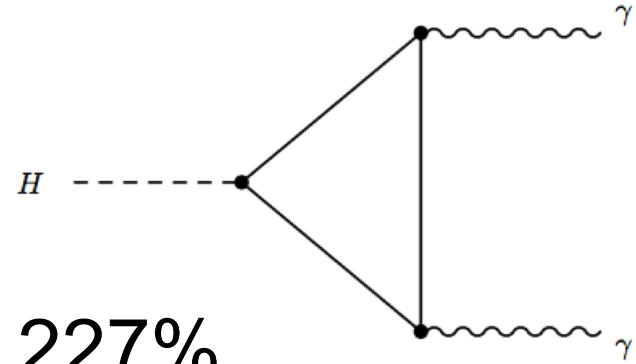
Higgs production
in pp collisions

- ttH production is a ***direct probe*** of the Higgs-top coupling
  - Indirect probes include gluon-gluon fusion production and $H \rightarrow \gamma\gamma$ decay loops
- Standard model σ_{ttH} is only 0.51 pb at 13 TeV



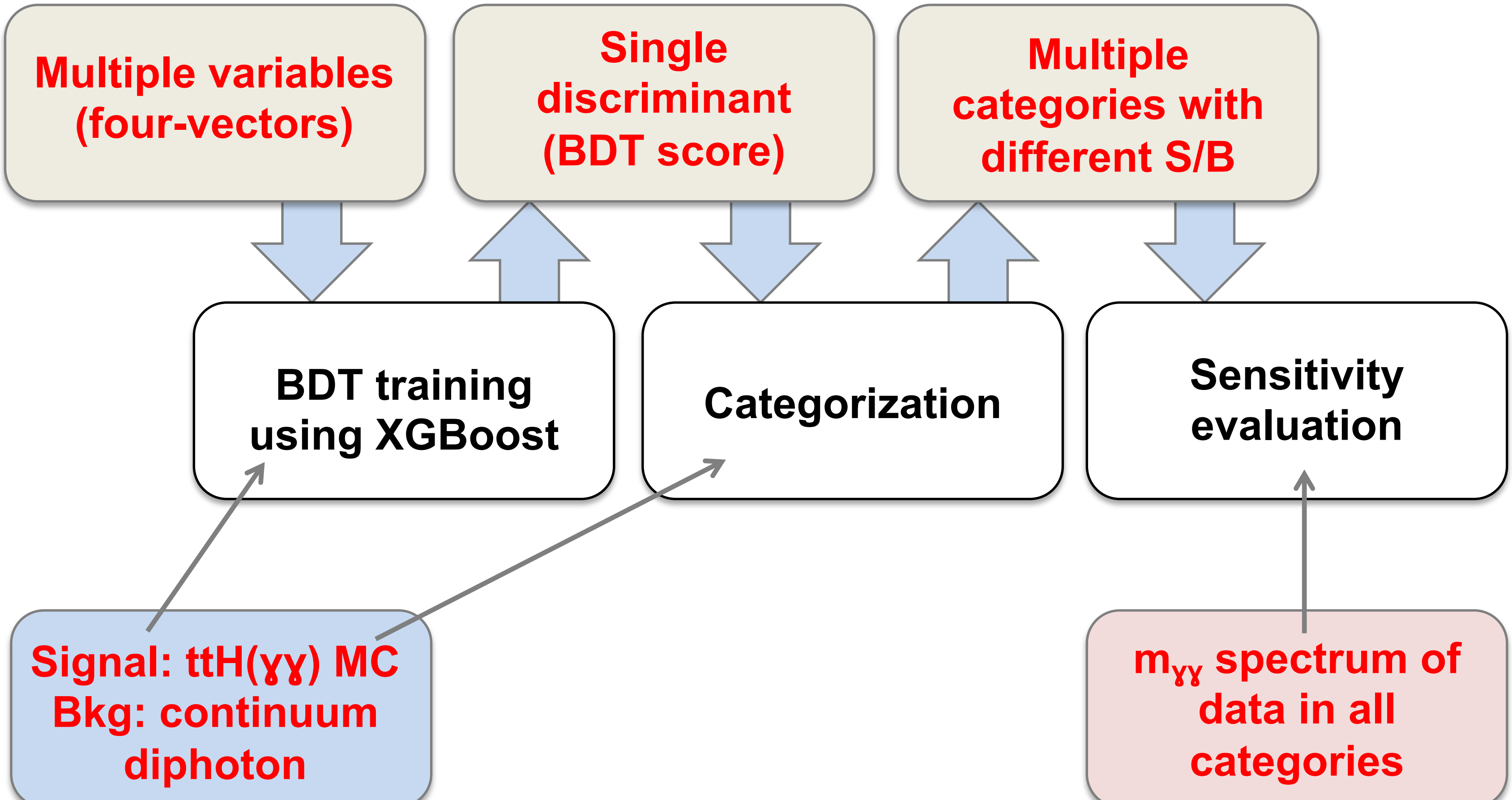


Why $H \rightarrow \gamma\gamma$?



- 🙁 Con: low branching ratio = 0.227%
- 🙂 Pro: manageable background
  - ***Low rates*** of photons compared to jets
  - ***Smoothly falling background*** $m_{\gamma\gamma}$ spectrum
- 🙂 Pro: excellent photon energy resolution
- 🙂 Pro: no ambiguity in the origin of final state particles
  - Photons from Higgs, all other objects from tops
- 🙂 Pro: expect big gains with more data

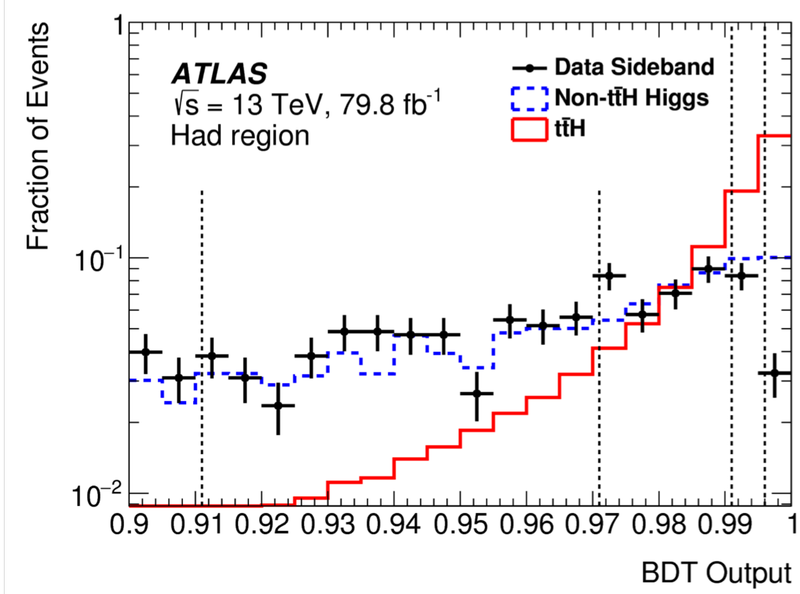
Multivariate analysis



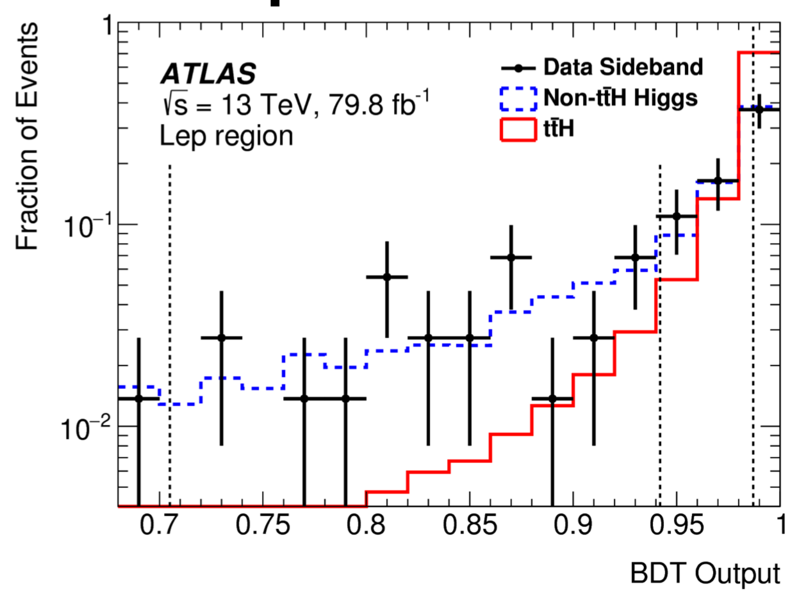
Multivariate analysis

- Define ttH categories with different S/B by slicing in BDT score
  - Tight BDT categories have lower statistics in data, but higher ttH purity and better S/B ratio

All-hadronic



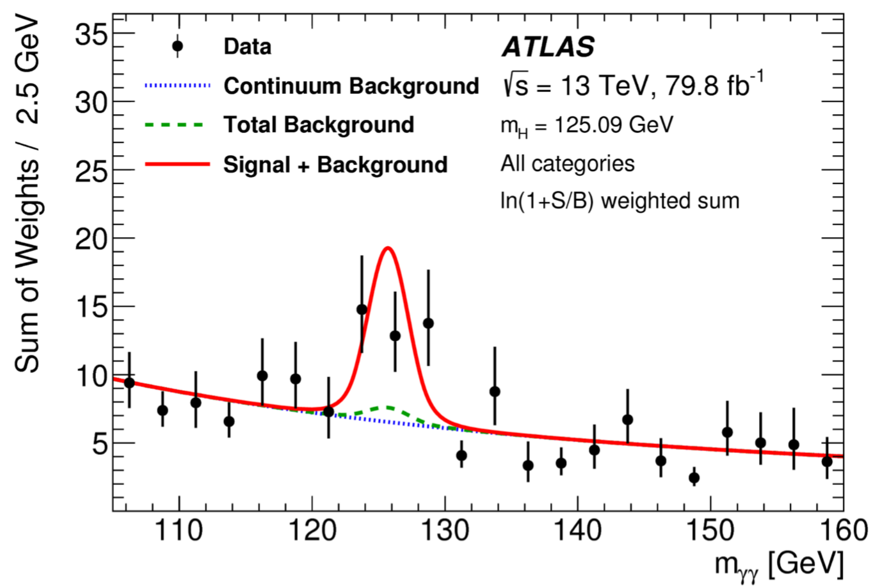
1+ lepton



Sensitivity to ttH(→ γγ)

with 79.8 fb^{-1}

- Perform a combined signal + background fit over all categories to the $m_{\gamma\gamma}$ distribution
- H → γγ alone is ***sensitive to ttH at the level of 4.1σ***
- ***Statistics limited!*** Expect further improvement with 2018 data

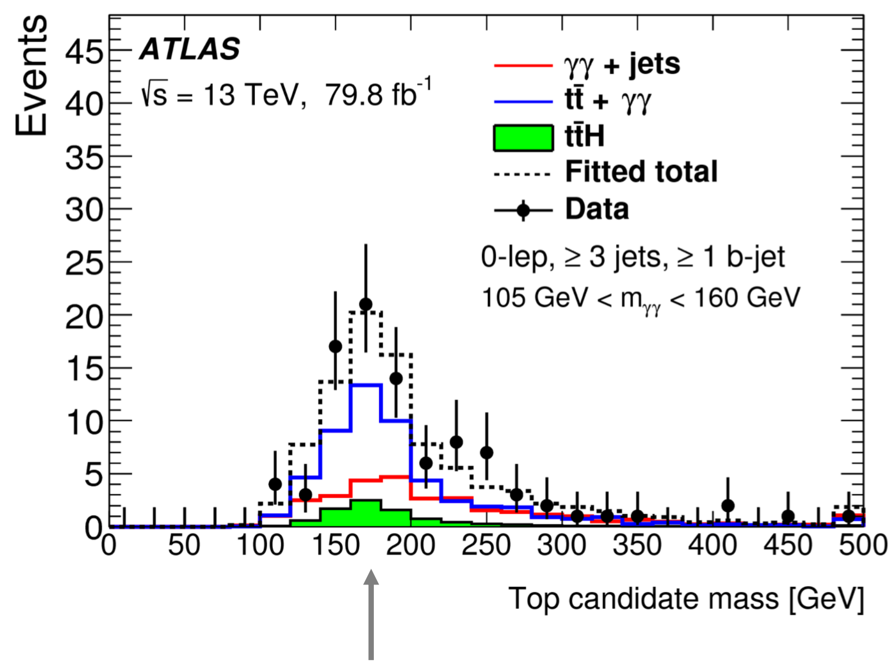


Top content

in ttH(→ γγ) categories

- Using a dedicated BDT algorithm, ***reconstruct top candidates*** from sets of three jets

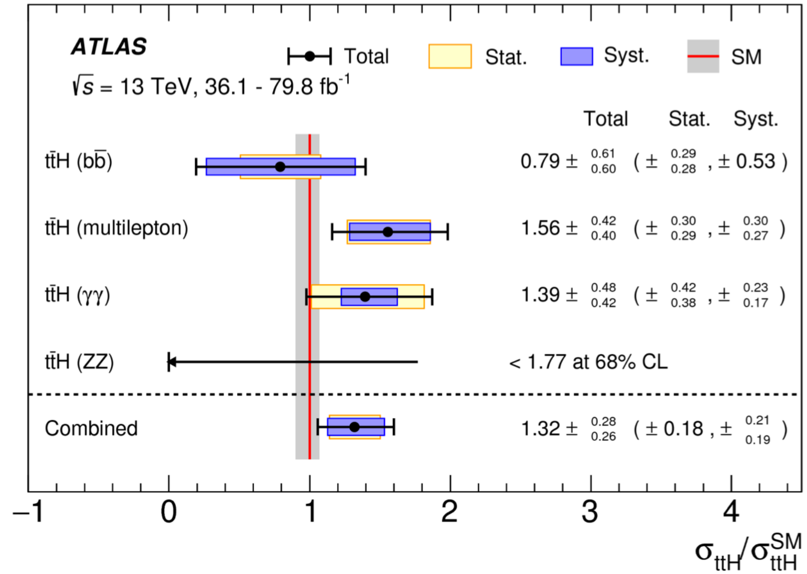
- ***Clear peak*** in data at m_{top} in the ttH(→ γγ) categories!
- Fit data to decompose continuum diphoton background into 58% ttγγ and 32% γγ



m_{top} = 173 GeV

Discovery of ttH

- We combine the ttH(→γγ) categories with other Higgs decay channels

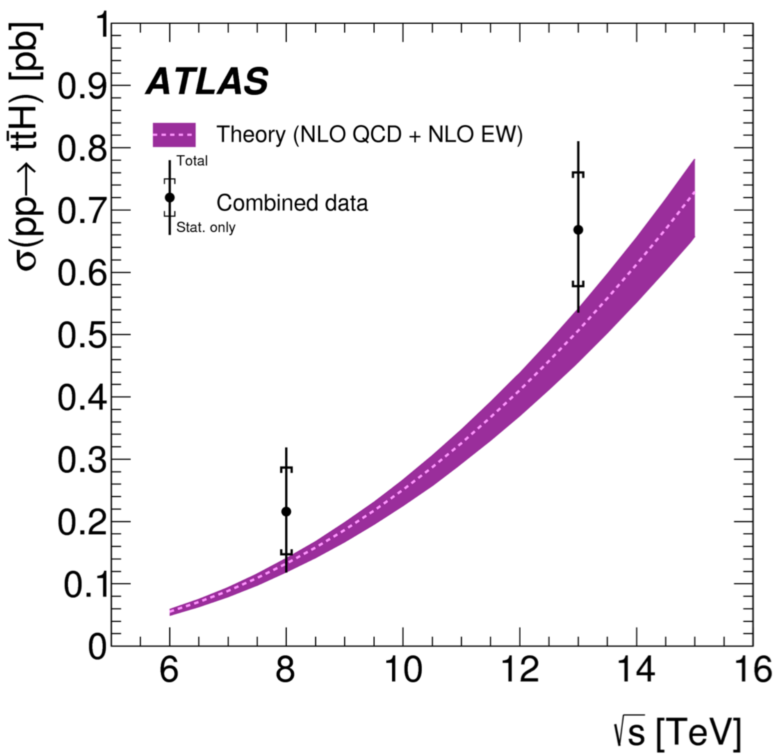


- We observe ttH production with a ***combined significance of 6.3σ***
- This is the first observation of ***direct Higgs-quark coupling!***

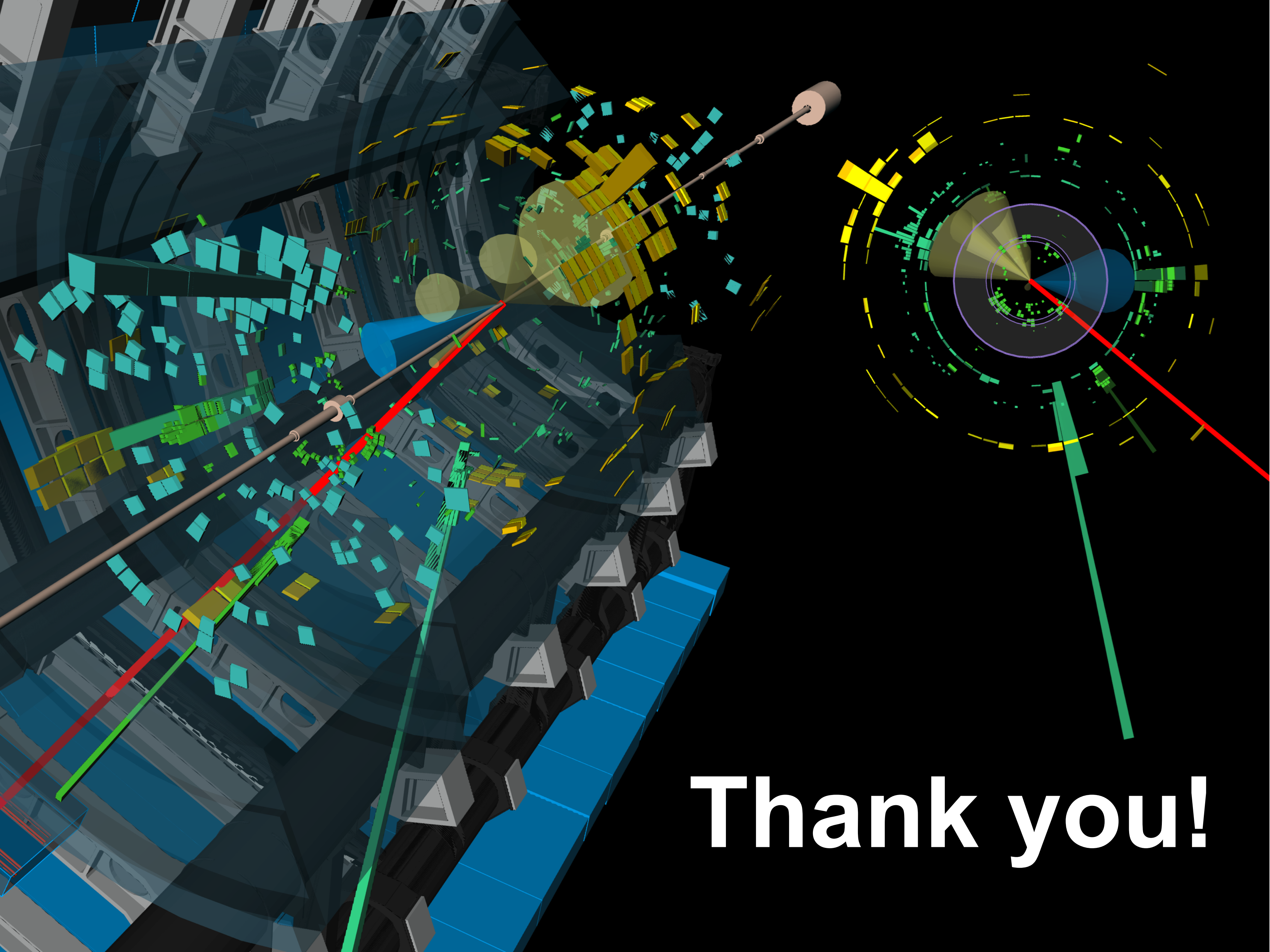
Discovery of ttH

- We measure a 13 TeV ttH cross section of

$$\sigma_{\mathrm{ttH}} = 670 \pm 90\ (\mathrm{stat})\ ^{+110}_{-100}\ (\mathrm{syst})\ \mathrm{fb}$$



- Reasonable agreement with the SM prediction
- We look forward to probing this process further in the full Run-2 dataset!



Thank you!

Backup

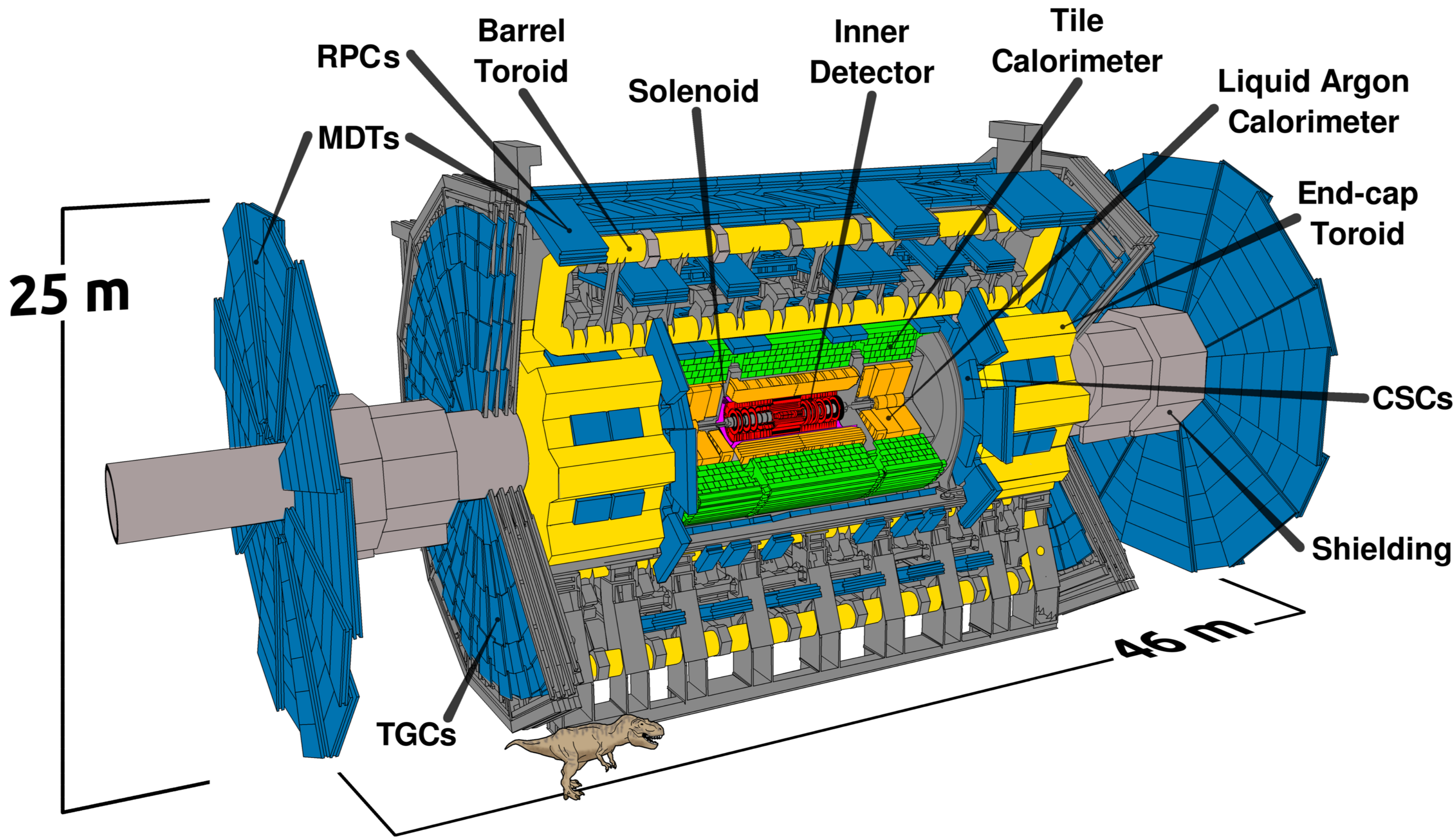
Abstract

Higgs production in association with top quarks (ttH) is predicted by the Standard Model at a rate of about 1% of the total Higgs cross section. This process directly probes the Higgs-top coupling, a critical parameter for isolating Beyond the Standard Model contributions to Higgs physics. The ATLAS search for ttH events in conjunction with the decay $H \rightarrow \gamma\gamma$ takes advantage of the high photon detection efficiency and energy resolution of the ATLAS electro-magnetic calorimeter, as well as the relatively low rate of diphoton background processes. The application of sophisticated multivariate techniques to identify $ttH \rightarrow \gamma\gamma$ events improves the sensitivity to ttH compared to past analyses. In combination with other Higgs decay channels, $ttH \rightarrow \gamma\gamma$ contributed to the recent discovery of the ttH production mode.

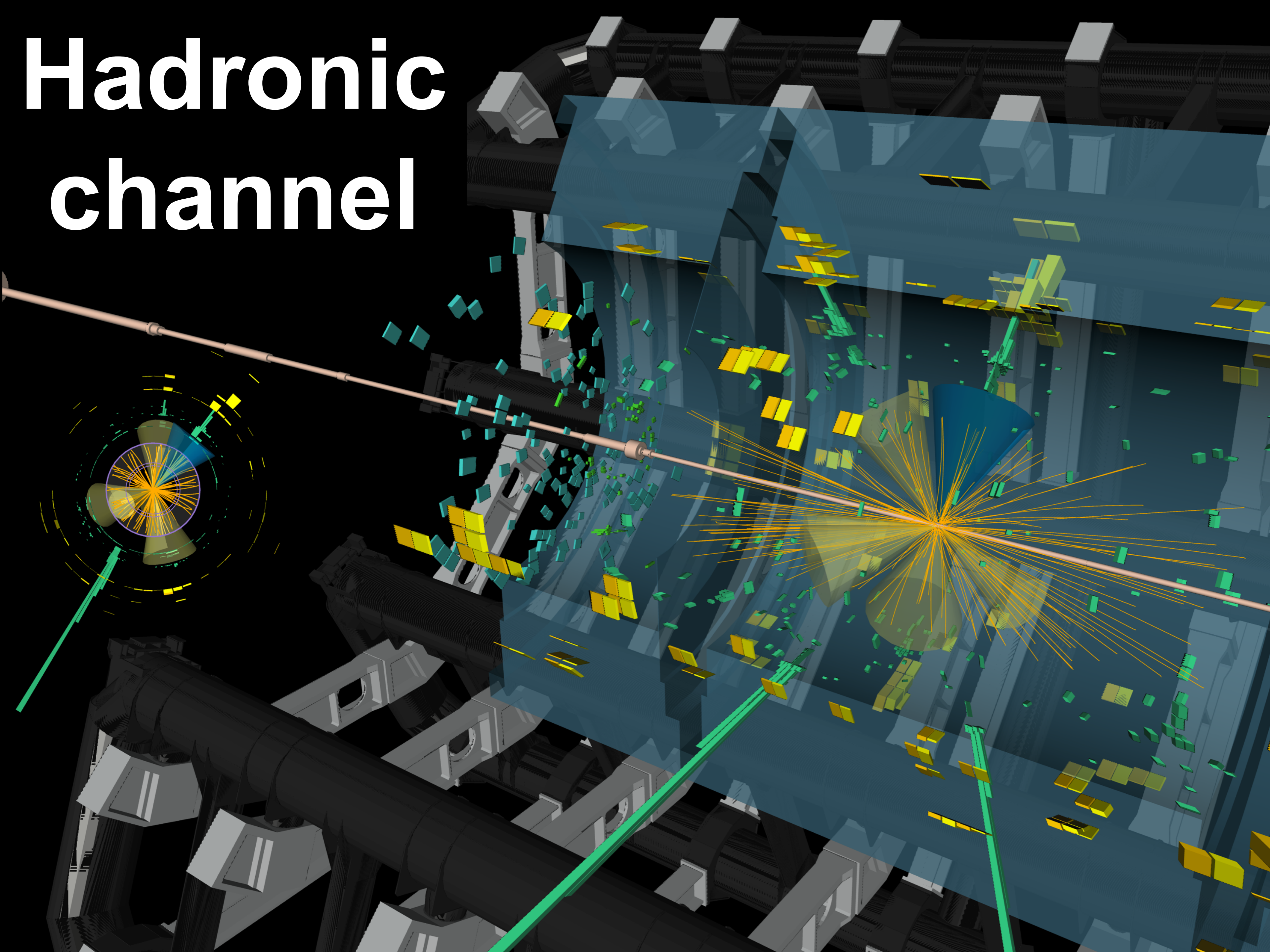
References

- ATLAS publications
  - ATLAS ttH discovery (June 2018): https://arxiv.org/pdf/1806.00425.pdf
- Other
  - http://pdg.lbl.gov/2016/reviews/rpp2016-rev-higgs-boson.pdf
  - https://twiki.cern.ch/twiki/bin/view/%20LHCPhysics/LHCHXSWG#SM_Higgs
  - ATLAS CONF $H \rightarrow \gamma\gamma$ (July 2018): http://cdsweb.cern.ch/record/2628771

The ATLAS detector



Hadronic channel



BDT Training

in the hadronic channel

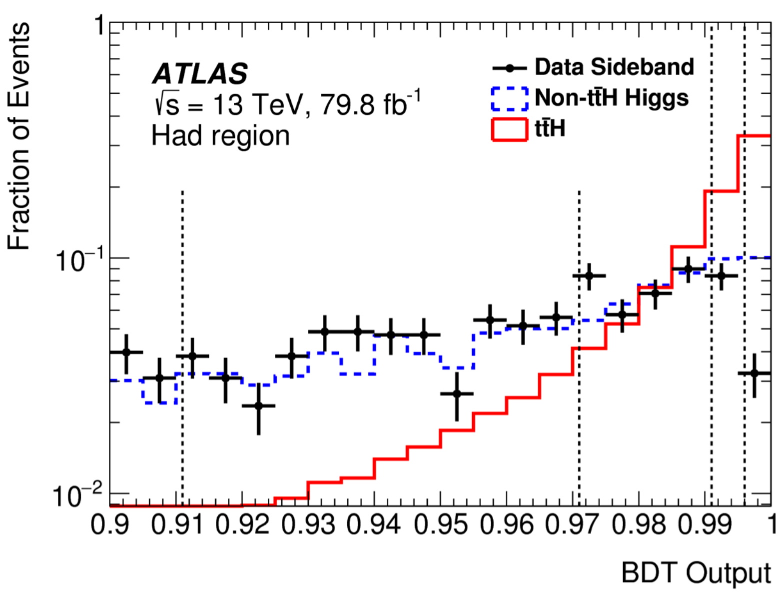
- Require ≥3 jets, ≥1 b-jet, 0 leptons
- Signal: ttH(ɣɣ) MC
- Background: data control sample + ggH(ɣɣ) MC
- Training variables:
  - Four momentum and b-tag score of up to six jets
  - Four momentum of the two photons, scaled by $m_{\gamma\gamma}$ to prevent biasing the $m_{\gamma\gamma}$ distribution
  - Missing E_T and angle of missing E_T

Category Definition

in the hadronic channel

- Define four hadronic ttH categories with different S/B by slicing in BDT score
  - Reject events with BDT score < 0.91

- Tight BDT categories have lower statistics, but higher ttH purity and better S/B ratio
  - These are the most powerful categories



Hadronic channel

BDT category 4 (loosest)

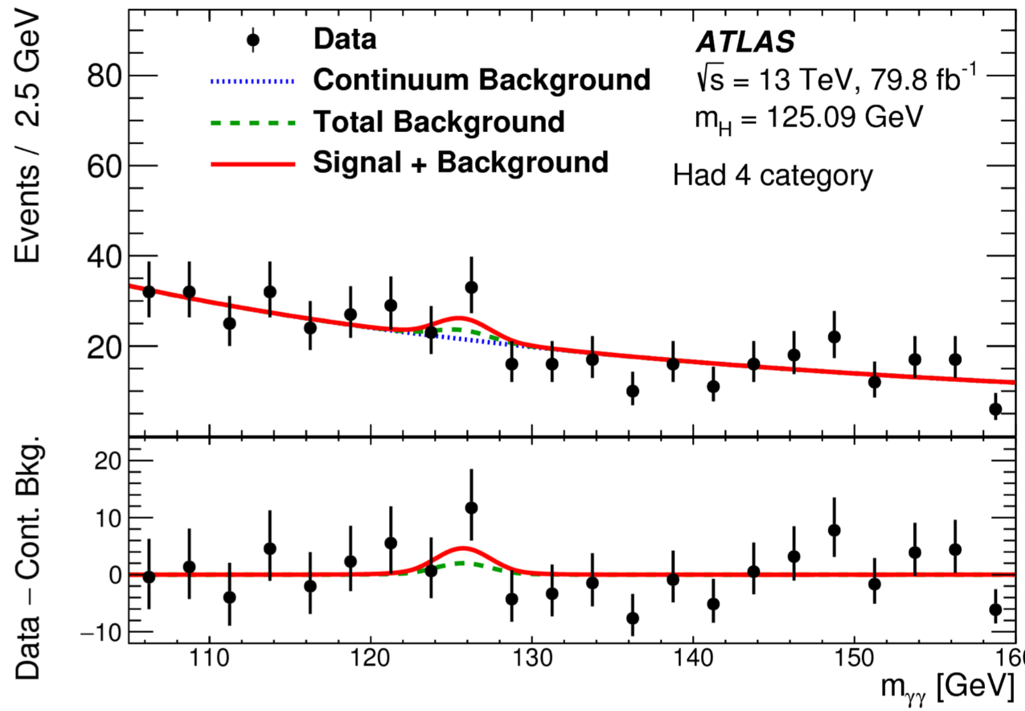
Expected ttH yield:
3.00

S/B: 0.05

ttH purity (n_{ttH}/n_{Higgs}):
48%

Background shape:
Power law

Mass resolution:
1.63 GeV



S/B and purity calculated in the smallest window containing 90% of ttH

Hadronic channel

BDT category 3

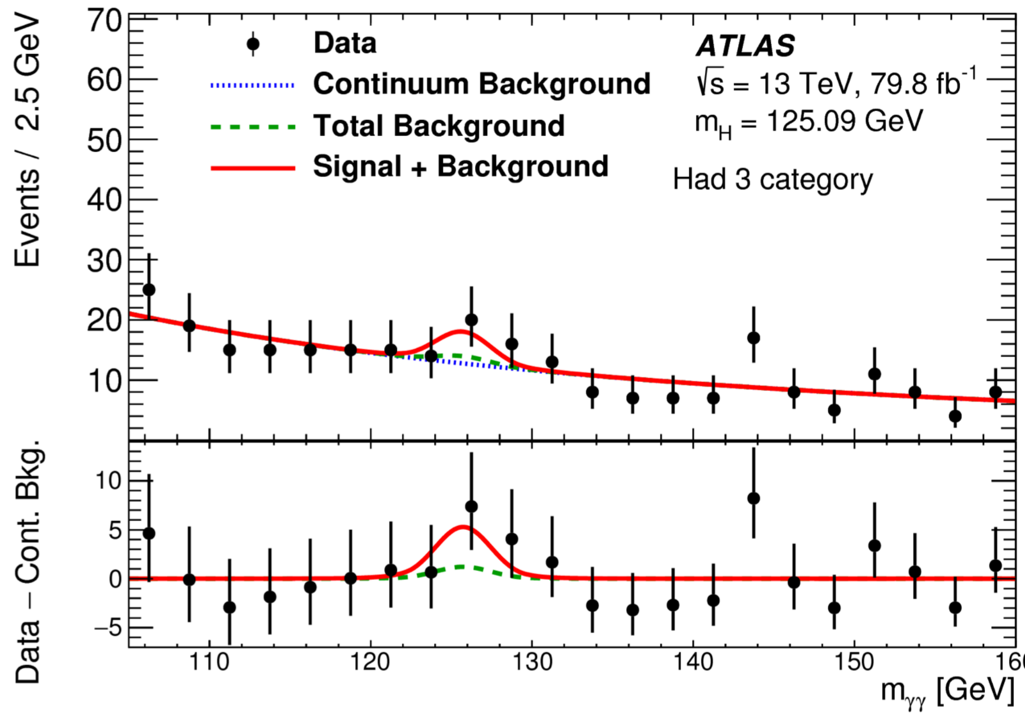
Expected ttH yield:
4.7

S/B: 0.13

ttH purity (n_{ttH}/n_{Higgs}):
70%

Background shape:
Power law

Mass resolution:
1.59 GeV



S/B and purity calculated in the smallest window containing 90% of ttH

Hadronic channel

BDT category 2

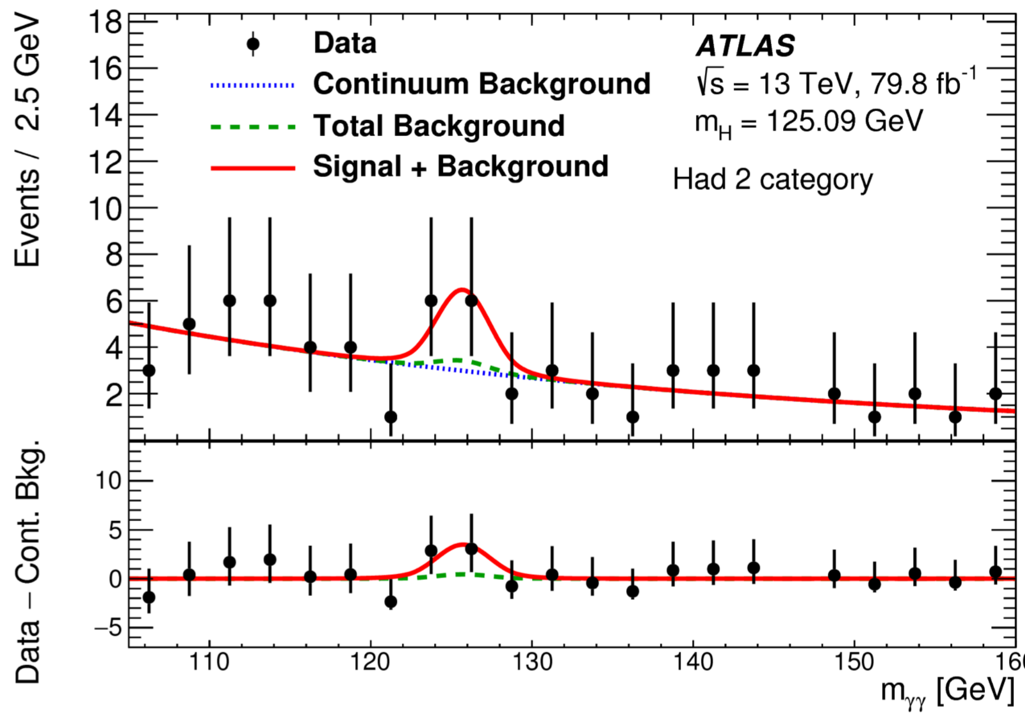
Expected ttH yield:
3.41

S/B: 0.42

ttH purity (n_{ttH}/n_{Higgs}):
83%

Background shape:
Exponential

Mass resolution:
1.46 GeV



S/B and purity calculated in the smallest window containing 90% of ttH

Hadronic channel

BDT category 1 (tightest)

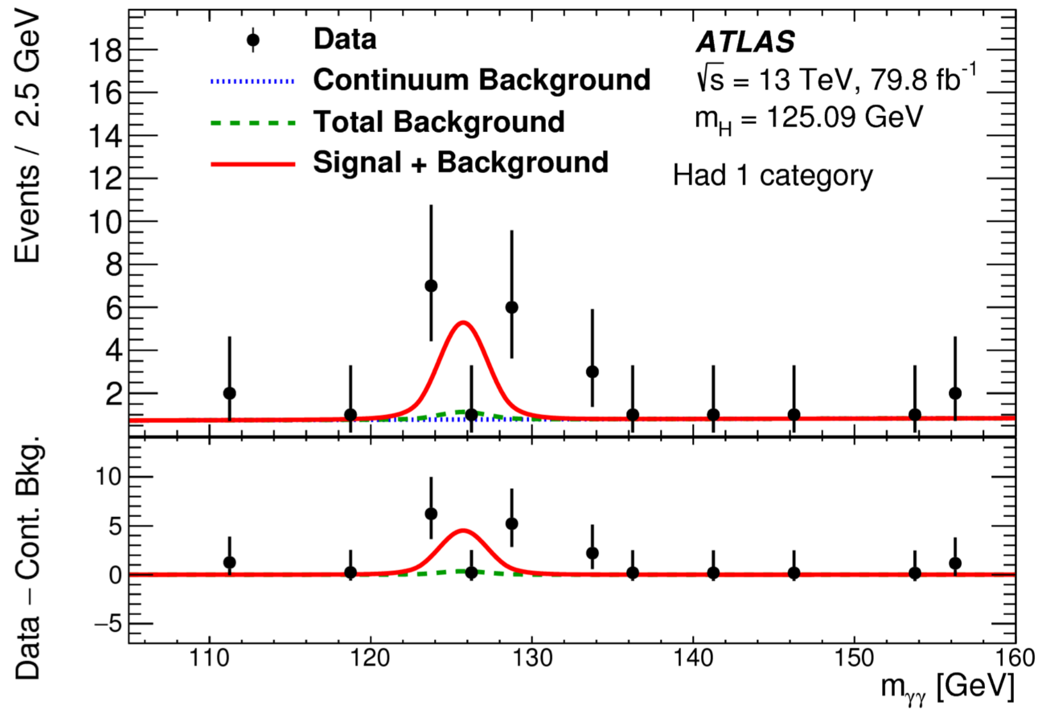
Expected ttH yield:
4.20

S/B: 1.87

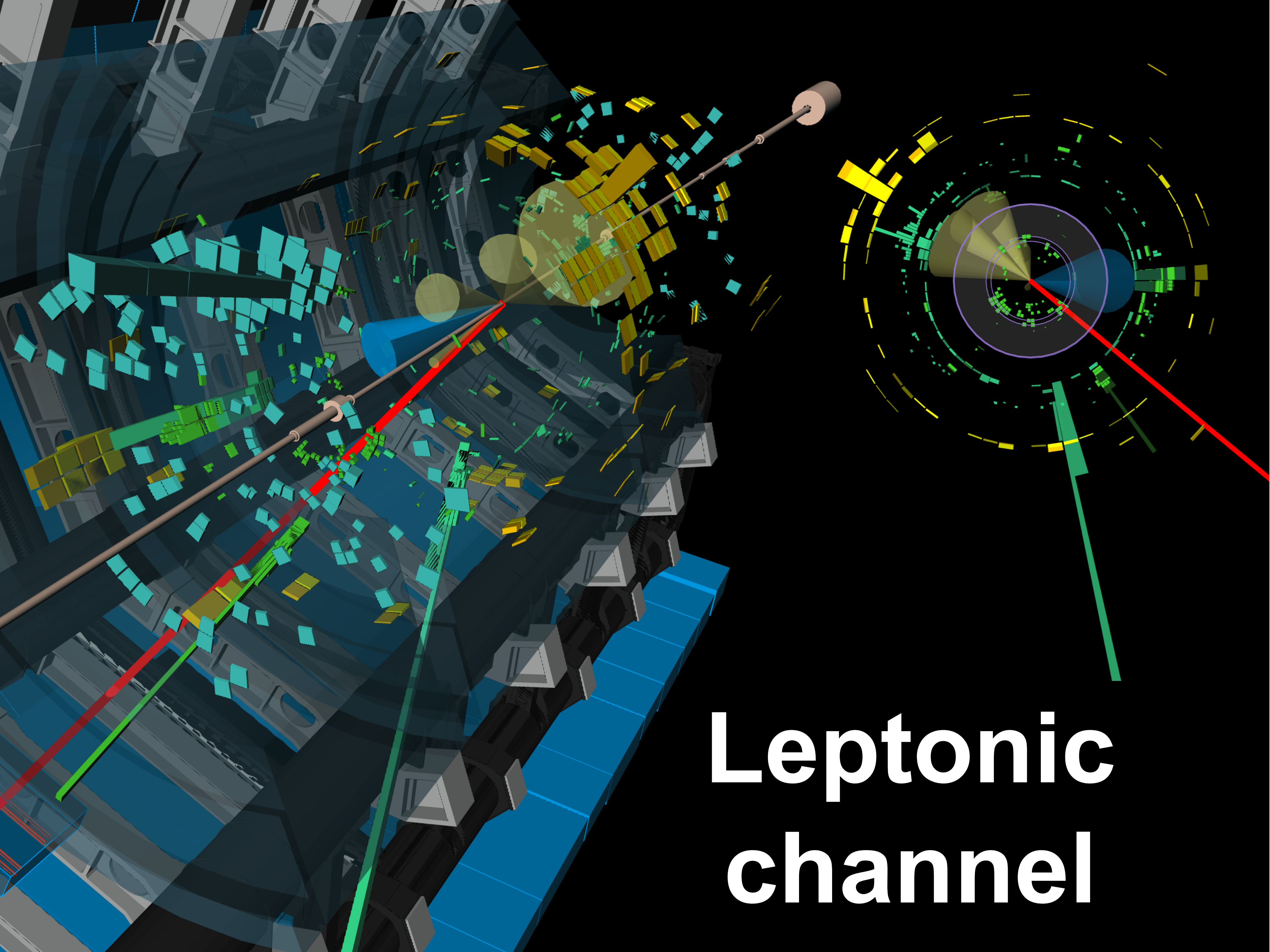
ttH purity (n_{ttH}/n_{Higgs}):
90%

Background shape:
Power law

Mass resolution:
1.32 GeV



S/B and purity calculated in the smallest window containing 90% of ttH



Leptonic channel

BDT Training

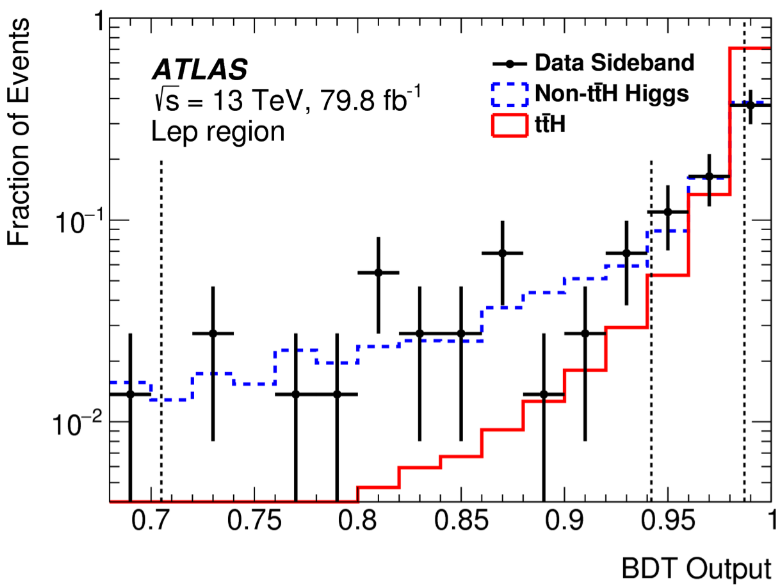
in the leptonic channel

- Require ≥3 jets, ≥1 b-jet, 0 leptons
- Signal: ttH(γγ) MC
- Background: data control sample
- Training variables:
  - Four momentum and b-tag score of up to six jets
  - Four momentum of the two photons, scaled by $m_{\gamma\gamma}$ to prevent biasing the $m_{\gamma\gamma}$ distribution
  - Four momentum of up to two leptons
  - Missing E_T and angle of missing E_T

Category Definition

in the leptonic channel

- Define three leptonic ttH categories with different S/B by slicing in BDT score
  - Reject events with BDT score < 0.70
- Again, tightest BDT category is the most powerful due to high S/B
- Statistics in the leptonic channel are lower
  - Branching ratio of W to eν or μν is only 21.3%



Leptonic channel

BDT category 3 (loosest)

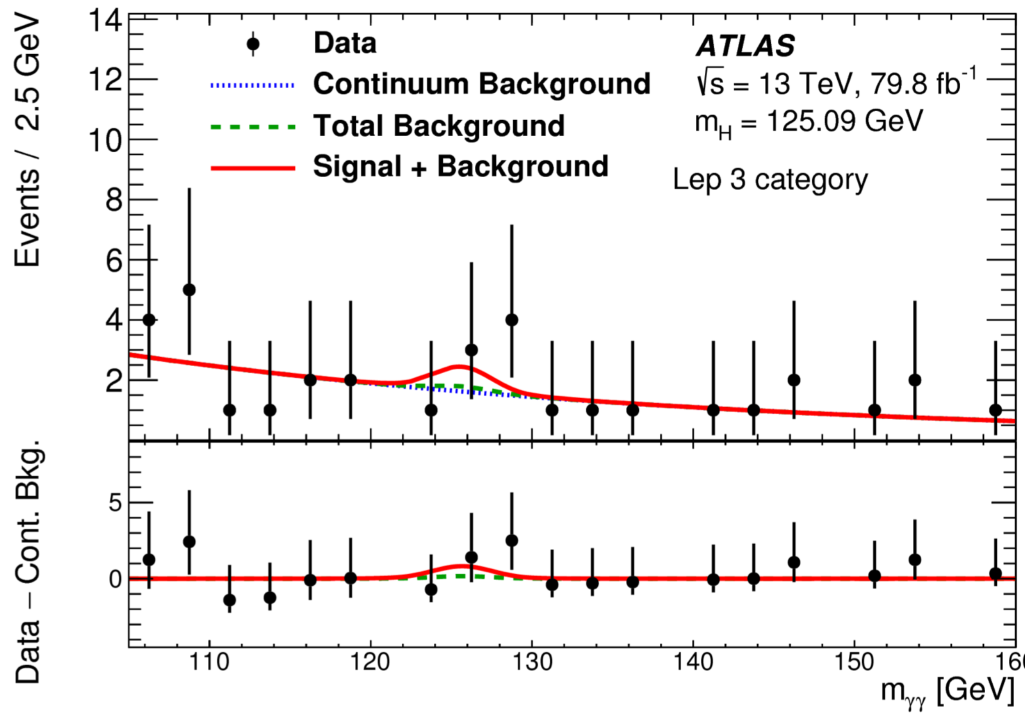
Expected ttH yield:
0.82

S/B: 0.17

ttH purity (n_{ttH}/n_{Higgs}):
73%

Background shape:
Exponential

Mass resolution:
1.73 GeV



S/B and purity calculated in the smallest window containing 90% of ttH

Leptonic channel

BDT category 2

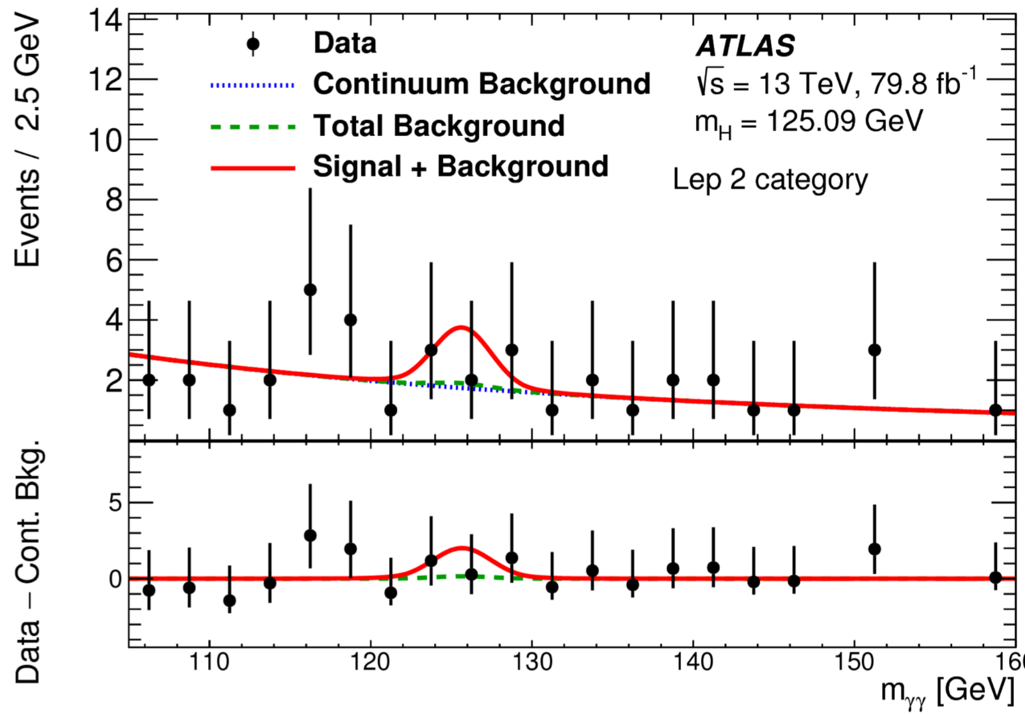
Expected ttH yield:
2.23

S/B: 0.46

ttH purity (n_{ttH}/n_{Higgs}):
89%

Background shape:
Power law

Mass resolution:
1.68 GeV



S/B and purity calculated in the smallest window containing 90% of ttH

Leptonic channel

BDT category 1 (tightest)

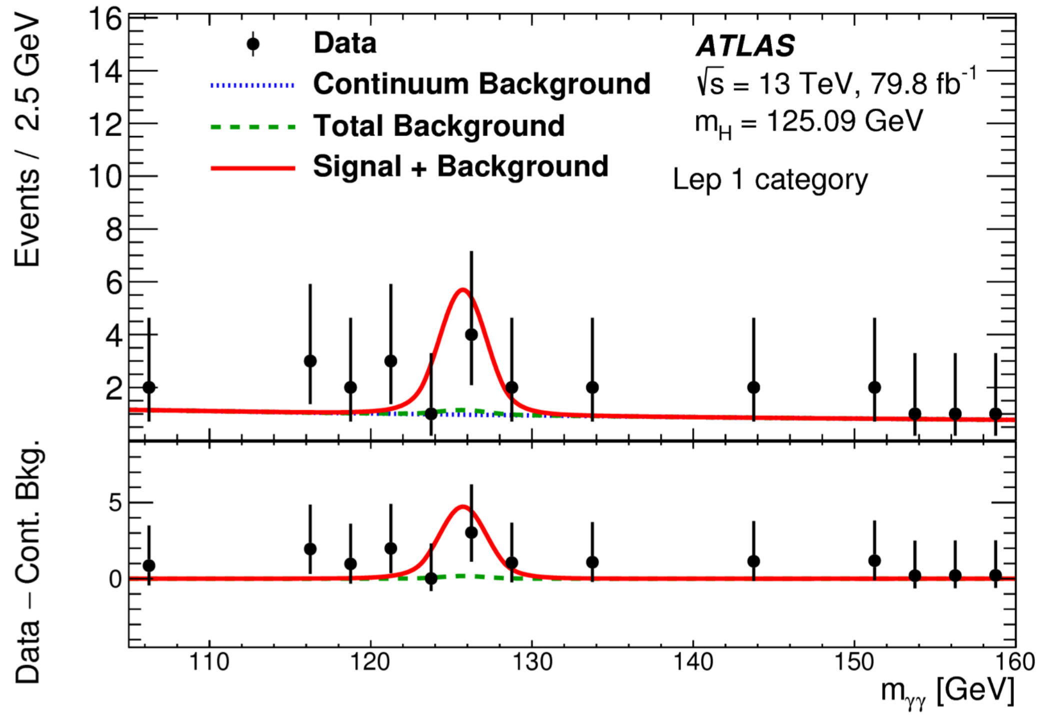
Expected ttH yield:
4.50

S/B: 1.84

ttH purity (n_{ttH}/n_{Higgs}):
95%

Background shape:
Power law

Mass resolution:
1.45 GeV



S/B and purity calculated in the smallest window containing 90% of ttH

Systematics

on the combined cross section measurement

Uncertainty source	$\Delta\sigma_{t\bar{t}H}/\sigma_{t\bar{t}H}$ [%]
Theory uncertainties (modelling)	11.9
$t\bar{t}$ + heavy flavour	9.9
$t\bar{t}H$	6.0
Non-$t\bar{t}H$ Higgs boson production modes	1.5
Other background processes	2.2
Experimental uncertainties	9.3
Fake leptons	5.2
Jets, $E_{\mathrm{T}}^{\mathrm{miss}}$	4.9
Electrons, photons	3.2
Luminosity	3.0
τ-lepton	2.5
Flavour tagging	1.8
MC statistical uncertainties	4.4