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ATLAS EXPERIMENT

Direct measurement of the top-quark decay width

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Overview

- Decay width of the top quark:
  - Measure for the lifetime
  - Can be increased by New Physics, like FCNCs, top→$H^{\pm}$, CKM modifying theories
  - Expected in SM: Γ_t = 1.322 GeV @NNLO (Phys. Rev. Lett. 110 (2013) 042001)
  - Previous ATLAS measurement yields: $\Gamma_t = 1.76 \pm 0.33(\text{stat.})\,^{+0.79}_{-0.68}(\text{syst.})$ GeV using 20.2 fb^{-1} @ 8 TeV (Eur. Phys. J. C 78 (2018) 129)

    → first “real“ measurement

- Here:
  direct measurement via kinematic reconstruction with full 13 TeV dataset (139 fb^{-1}) in top-pair events (ATLAS-CONF-2019-038)

Analysis strategy

Dilepton event selection

Kinematic reconstruction variables: m_{lb} and $m_{b\bar{b}}$

Template creation for various Γ_t

Profile likelihood fit to extract Γ_t

Event selection

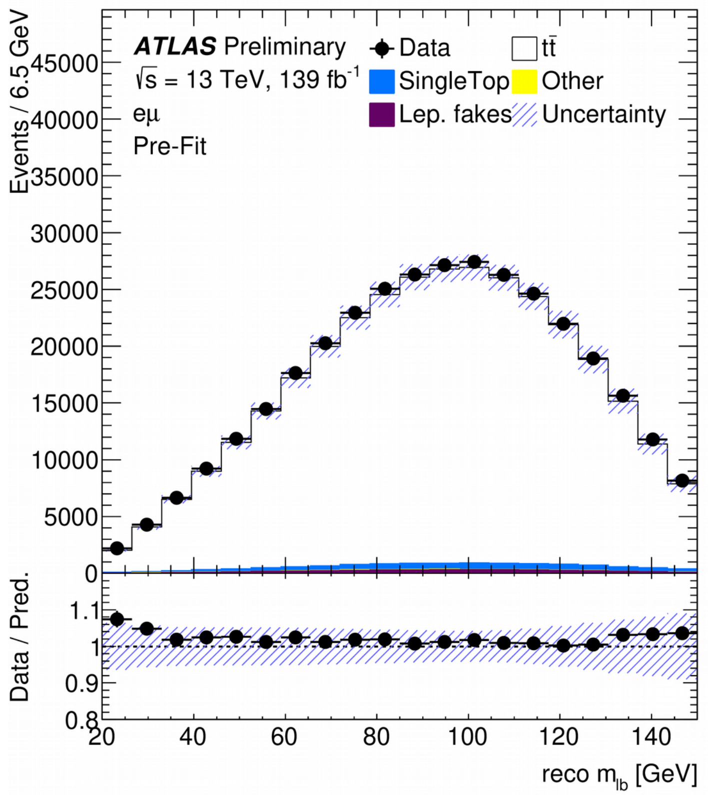
- Select ee, eμ and μμ events:
  - Single lepton triggers
  - Exactly two electrons or muons with p_T>25/27 GeV (2015/2016-2018)
  - At least two b-jets with p_T>25 GeV (b-tagging with 60% efficiency)
  - Z-veto and E_T^{miss}>60 GeV in ee and μμ

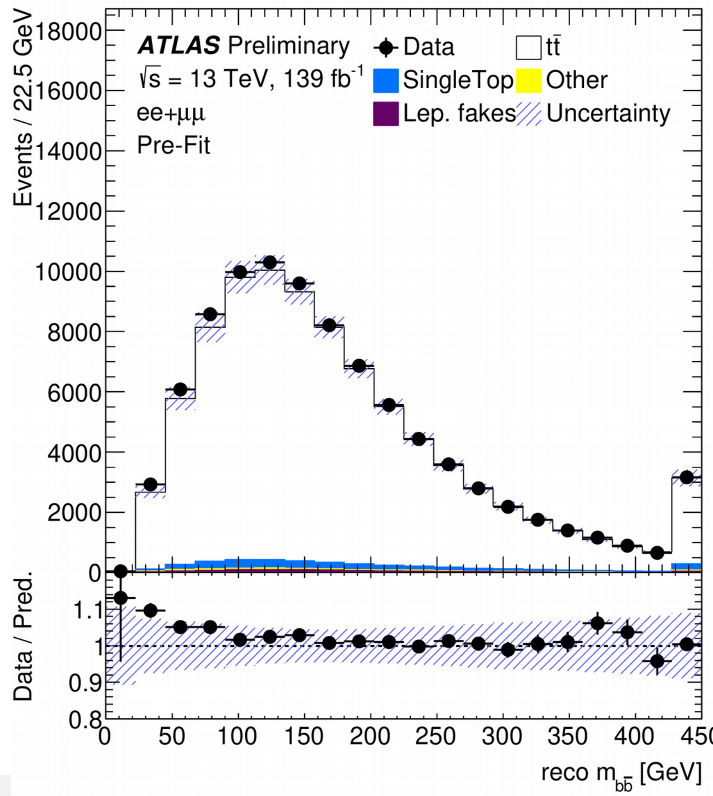
	ee	$\mu\mu$	$e\mu$
$t\bar{t}$	34000±1700	49100±2500	176000±9000
Single top	1150± 60	1570± 80	5300± 260
Z+VV+$t\bar{t}X$	230± 120	390± 200	380± 190
Fake leptons	800± 400	41± 20	2100±1100
Total prediction	37000±1800	51100±2500	184000±9000
Data	37926	52166	186951

- Event yields estimated from simulation:
  - For $t\bar{t}$: Powheg-Box-V2+Pythia8 scaled to NNLO+NNLL prediction

Kinematic reconstruction

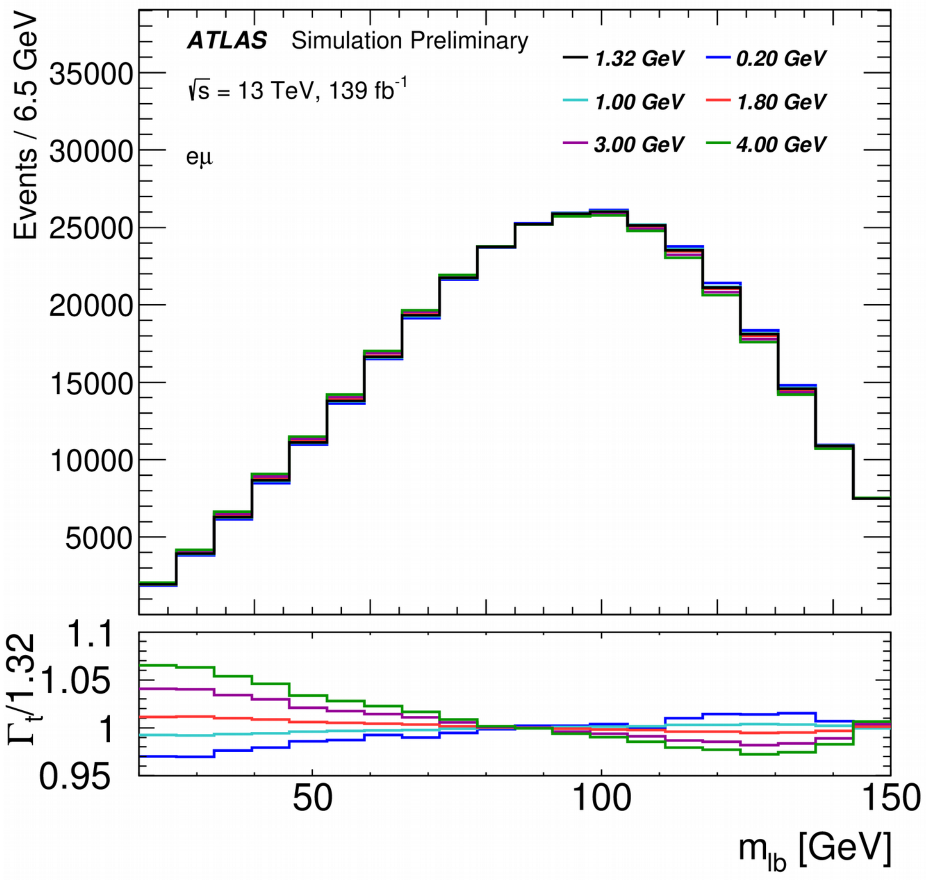
- Natural choice: invariant mass of the top quark
  - → Only accessible via decay products
  - → Would need neutrino reconstruction
- Alternative choice: m_{lb}
  - Combine leading p_T-lepton with closest b-jet in ΔR
  - Pair second lepton with remaining closest b-jet
  - Correct pairing found in 63% of the events
- In the likelihood fit:
  - Use m_{lb} to extract Γ_t in eμ region
  - Take $m_{b\bar{b}}$ in ee and μμ regions to constrain jet systematics





Template creation

- Need fit templates for various Γ_t values:
  - On truth level: m_t distribution described by Breit-Wigner (BW) function
  - Re-weight nominal MC sample with ratio of BW functions for different Γ_t values

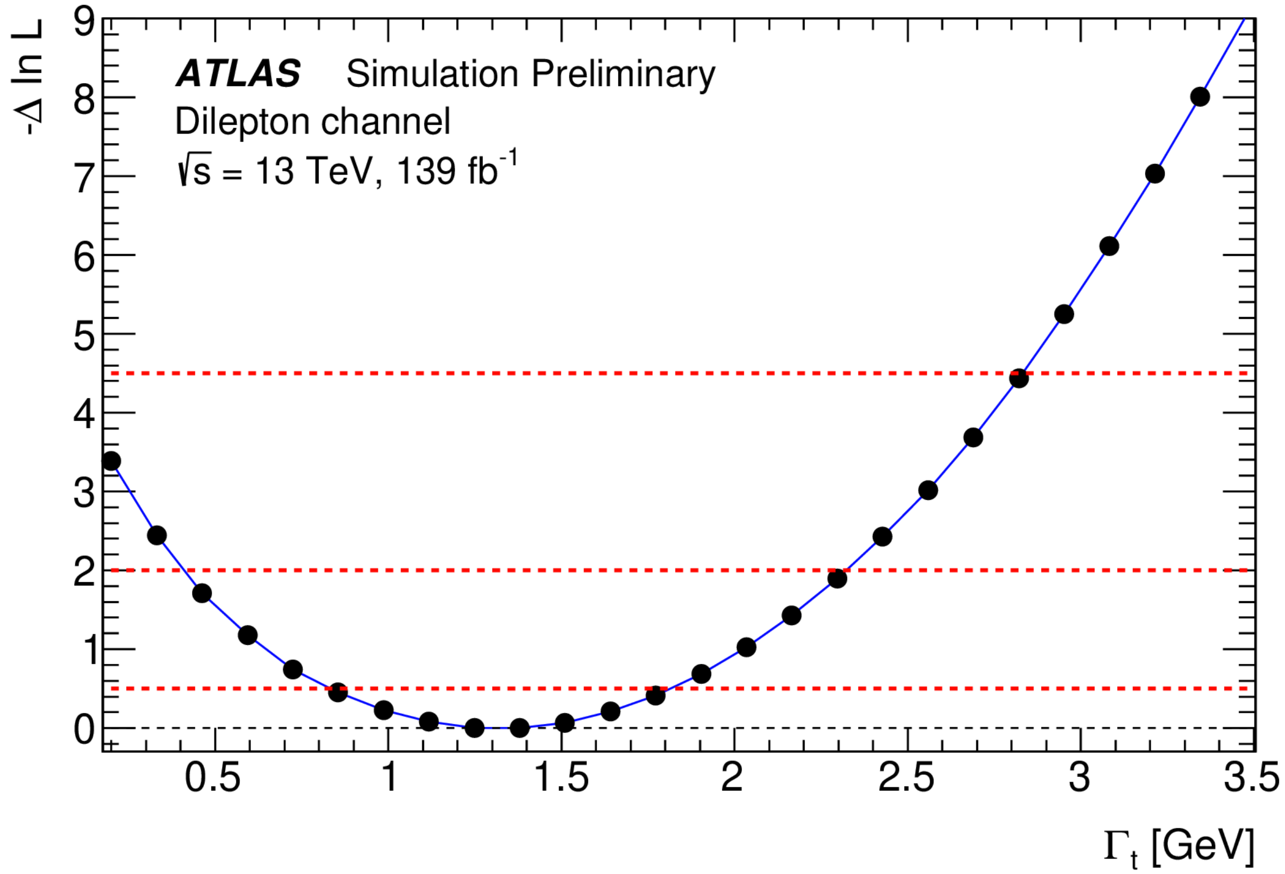


- **But**: need templates for continuous Γ_t values in likelihood fit
  - Solution: Interpolate between templates T_i

    Template $m_{lb}(\Gamma_t)=\Sigma\, w_i{}^*T_i$
  - Weight $w_i=w_i(\Gamma_t)$ taken from piece-wise linear interpolation

Likelihood fit

- Perform template profile likelihood fit to:
  - m_{lb} in eμ region
  - $m_{b\bar{b}}$ in ee and μμ regions
- Parameter of interest: Γ_t
  - Fit templates are interpolated as function of Γ_t
- Systematic uncertainties included as nuisance parameters
- Fit is tested with Asimov data:
  - Use SM prediction as input and perform likelihood scan



Fit validation

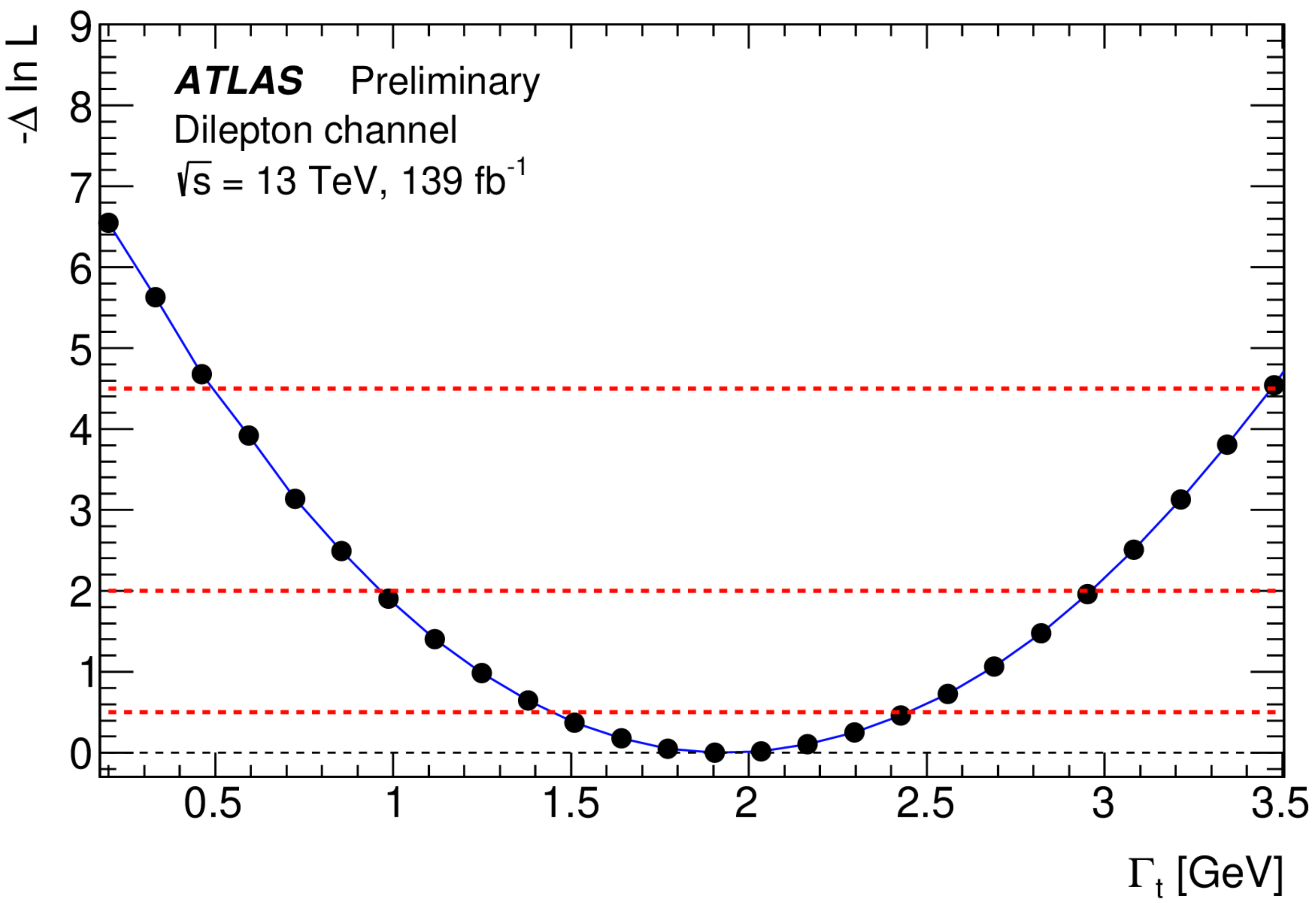
- Run the fit with different input Γ_t values

Input Γ_t [GeV]	Mean value [GeV]	Uncert. [GeV]
0.5	0.51	+0.42 −0.29
0.7	0.70	+0.47 −0.37
1.0	1.00	+0.49 −0.44
1.32	1.32	+0.49 −0.49
1.5	1.50	+0.50 −0.49
2.0	2.00	+0.52 −0.50
2.5	2.50	+0.54 −0.51

Fit results

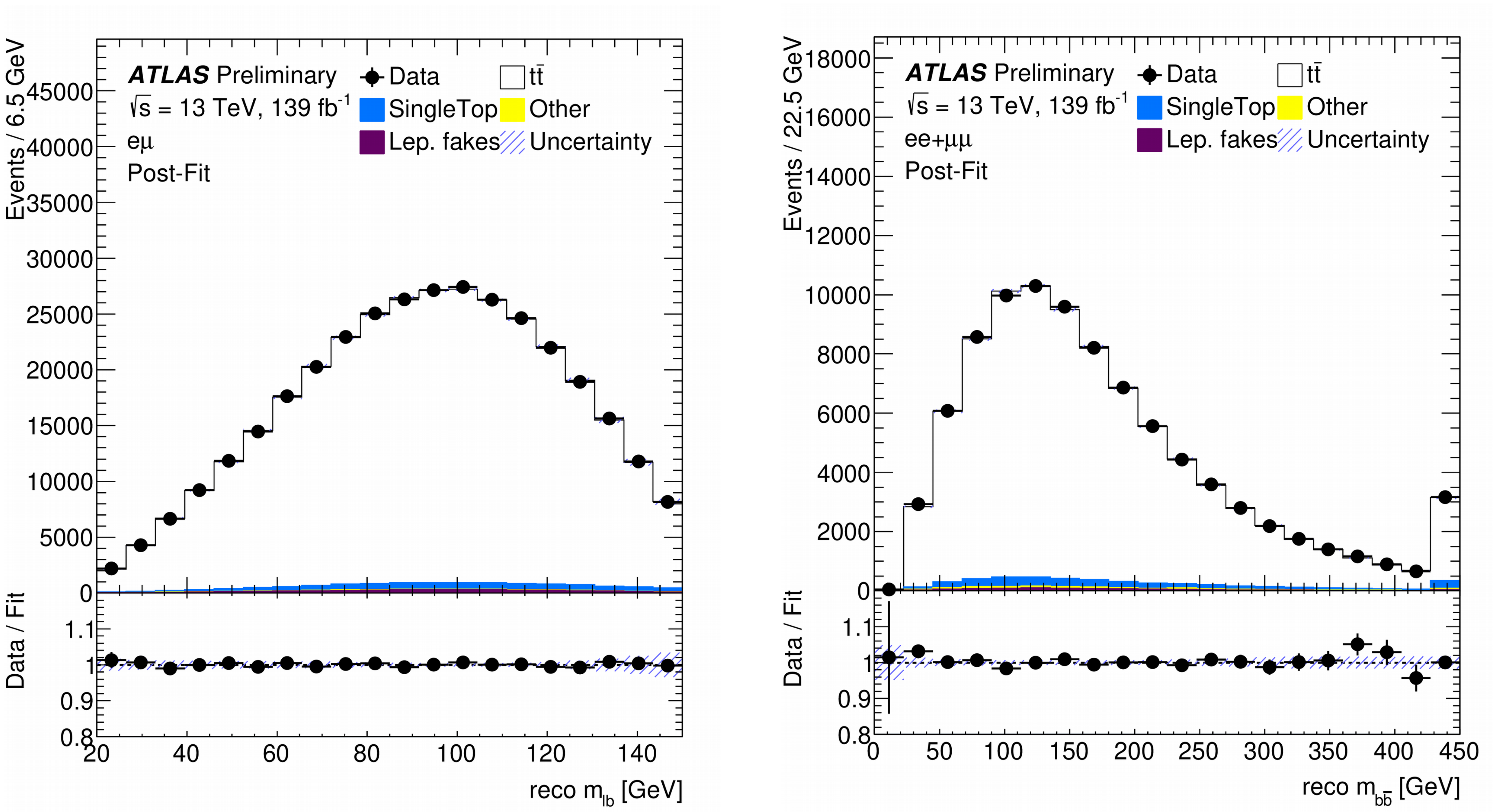
- Fit applied on data yields:

$$\Gamma_t = 1.94^{+0.52}_{-0.49}\ \text{GeV}$$



Source	Impact on Γ_t [GeV]
Jet reconstruction	±0.24
Signal and bkg. modelling	±0.19
MC statistics	±0.14
Flavour tagging	±0.13
E_T^{miss} reconstruction	±0.09
Pile-up and luminosity	±0.09
Electron reconstruction	±0.07
PDF	±0.04
$t\bar{t}$ normalisation	±0.03
Muon reconstruction	±0.02
Fake-lepton modelling	±0.01

Post-fit distributions



- Very good agreement between data and fitted model

Top-mass dependency

- Top width depends on top mass
- Default top mass: 172.5 GeV
- No systematic top-mass uncertainty considered
- To evaluate top-mass dependency, repeat fit with templates for m_t=172 and 173 GeV

	m_t = 172 GeV		m_t = 172.5 GeV		m_t = 173 GeV	
	Mean [GeV]	**Unc. [GeV]**	**Mean [GeV]**	**Unc. [GeV]**	**Mean [GeV]**	**Unc. [GeV]**
Measured	2.01	$^{+0.53}_{-0.50}$	1.94	$^{+0.52}_{-0.49}$	1.90	$^{+0.52}_{-0.48}$
Theory	1.306	< 1%	1.322	< 1%	1.333	< 1%

- Top mass shifts measured values as well as prediction slightly

Conclusion

- Analysis with full Run II dataset
- Kinematic reconstruction method to determine Γ_t
- Profile likelihood fit to extract Γ_t in dilepton $t\bar{t}$ events
- Most precise top-width measurement so far:

$$\Gamma_t = 1.9 \pm 0.5 \text{ GeV}$$

- Uncertainty dominated by jet and modelling uncertainties
- Compatible within 1-2 σ with the SM prediction of 1.322 GeV