Selected topics from single top Wt and s-channel production

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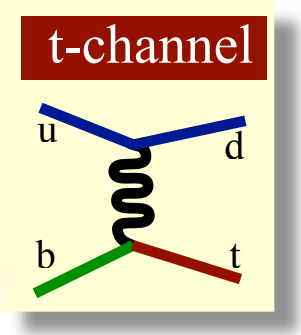
on behalf of the ATLAS and CMS Collaborations

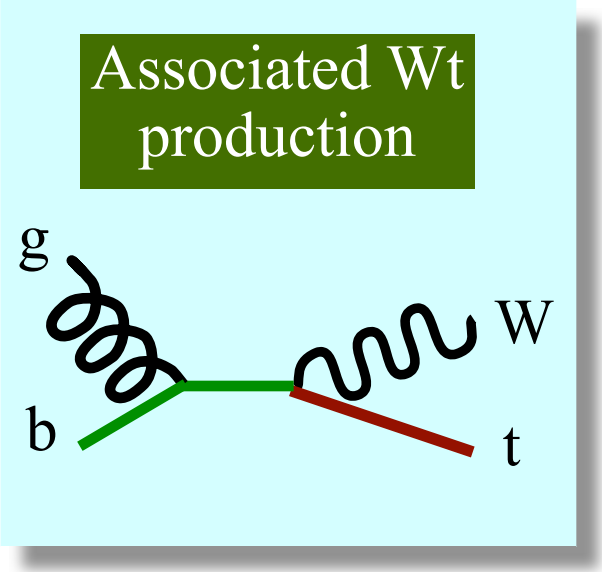
Outline

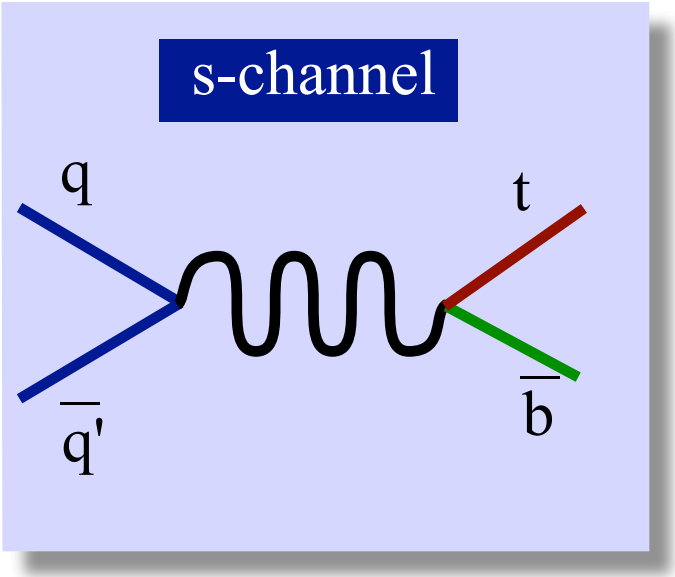
- Introduction
- Single top-quark production in association with a W boson
  - CMS
  - ATLAS
  - LHC combination
- CKM matrix element Vtb
- Single top-quark production in the s-channel
  - ATLAS
  - CMS
- Prospects for 13 TeV
- This talk will:
  - Focus on 8 TeV results
  - Assume a top-quark mass of 172.5 GeV

- Other LHC single top talk:
  - t-channel single top (Benedikt Maier, today)

Single top-quark production

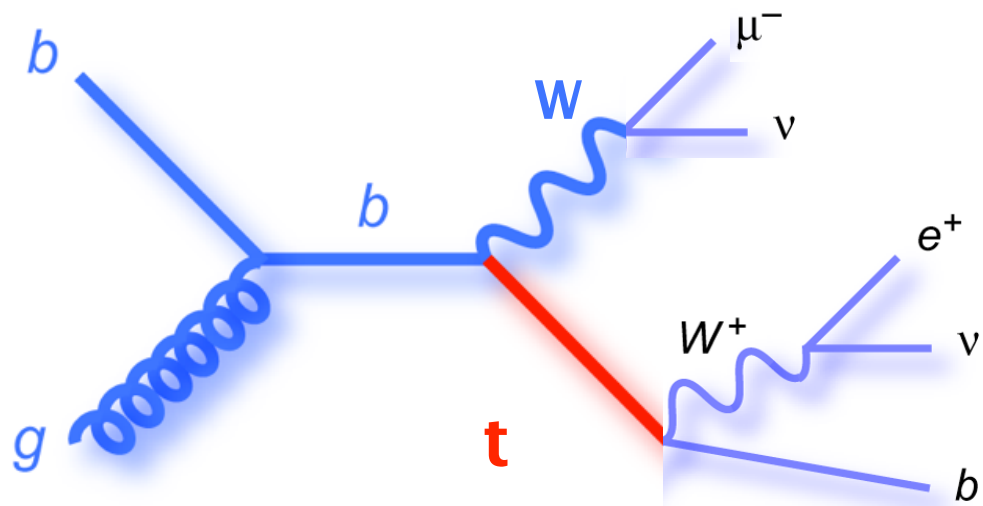






- Window to SM
  - CKM matrix element V_{tb}
  - Weak interaction of top quark
- Window to new physics
  - Resonances (W'), vector-like quarks, anomalous couplings
- Associated Wt production is unique to the LHC
  - Challenging measurement
  - Overlap/interference with top pair production
- s-channel is challenging at the LHC
  - Discovered at Tevatron through CDF+D0 combination

Single top-quark production in association with a W boson



$\sigma = 22.4 \pm 1.5$ pb at 8 TeV

NLO+NNLL
Kidonakis, PRD82 054018 (2010)

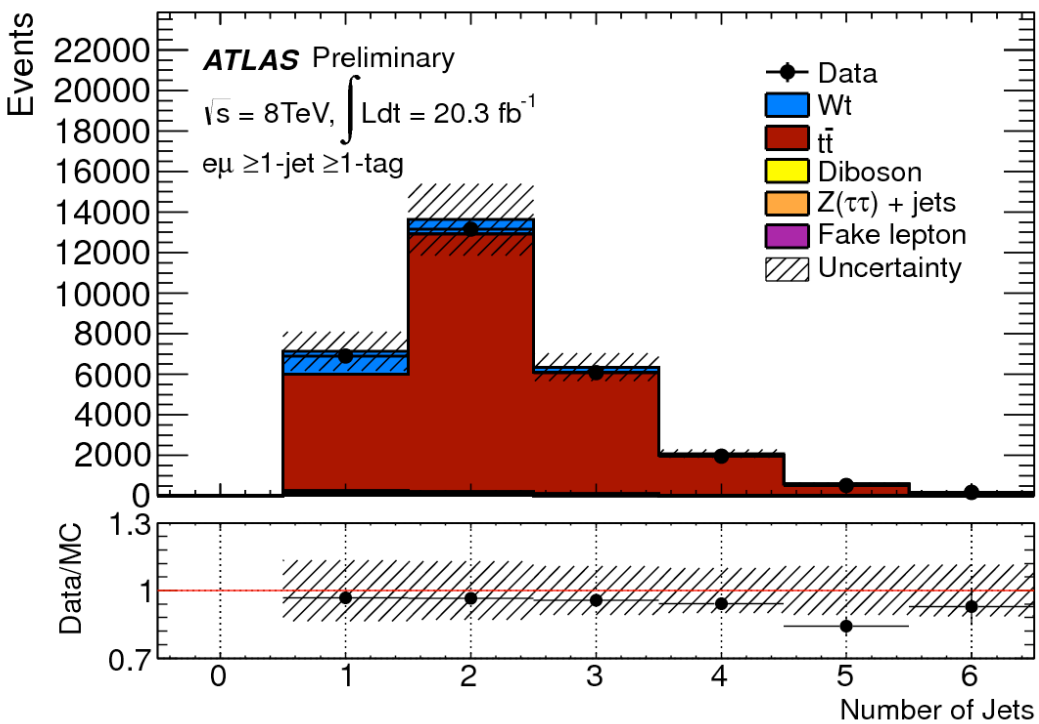
- Dilepton final state
- Separate analysis regions by # of jets and # of b-tags
- Dominated by systematic uncertainties
- Largest background is ttbar
- Overlap/interference with ttbar
  - See talk by Stefan Kallweit

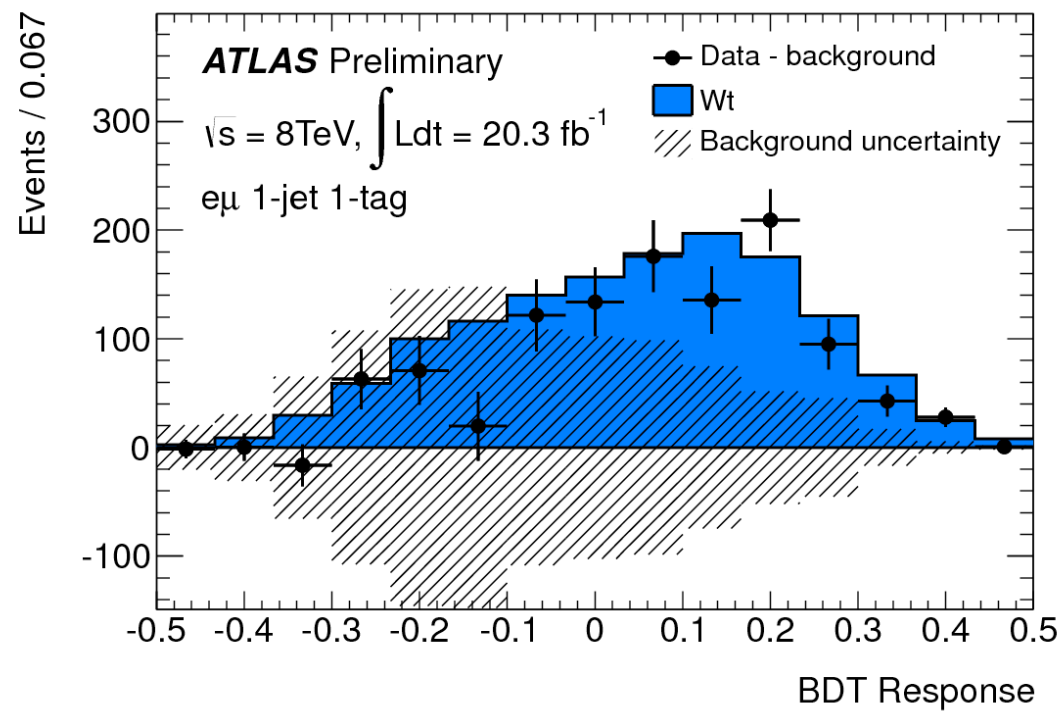
ATLAS Wt

- 8 TeV, 20 fb^{-1}
- eμ final state
- 1-jet 1-tag and 2-jet ≥1-tag
- BDT to isolate signal
- σ_{meas} = 27.2 ± 5.8 pb
- 4.2 s.d. significance

Largest systematic uncertainties

Source	$\Delta\sigma/\sigma$ [%] observed	$\Delta\sigma/\sigma$ [%] expected
Data statistics	7.1	8.6
Flavor tagging	8.4	9.4
$t\bar{t}$ generator and PS	7.5	9.2
Total (syst)	20	23
Total (syst+stat)	21	24





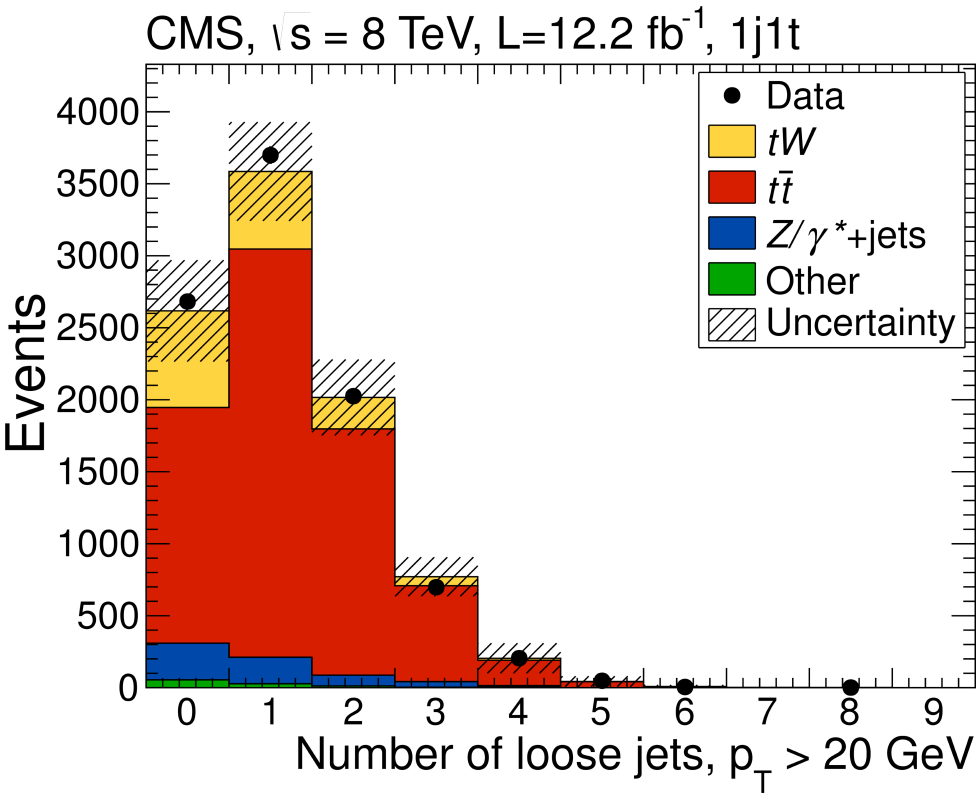
ATLAS-CONF-2013-100

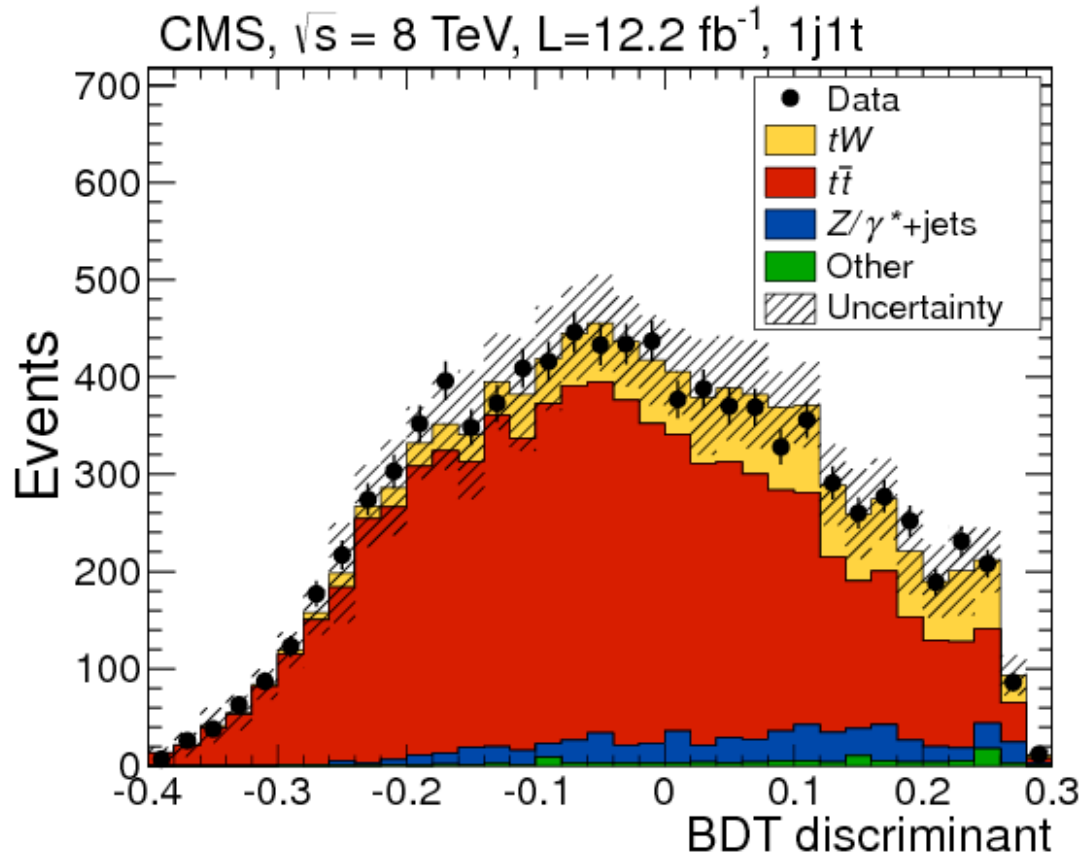
CMS Wt

- 8 TeV, 12.2 fb^{-1}
- ee, eμ, μμ
- 1- and 2-jet with 1- and 2-tag
- BDT to isolate signal
- σ_{meas} = 23.4 ± 5.4 pb
- 6.1 s.d. significance
- First observation of Wt

Largest systematic uncertainties

Systematic uncertainty	$\Delta\sigma/\sigma$
ME/PS matching thresholds	14%
Renormalization/factorization scale	12%
Top-quark mass	9%
Fit statistical	8%
Total	24%





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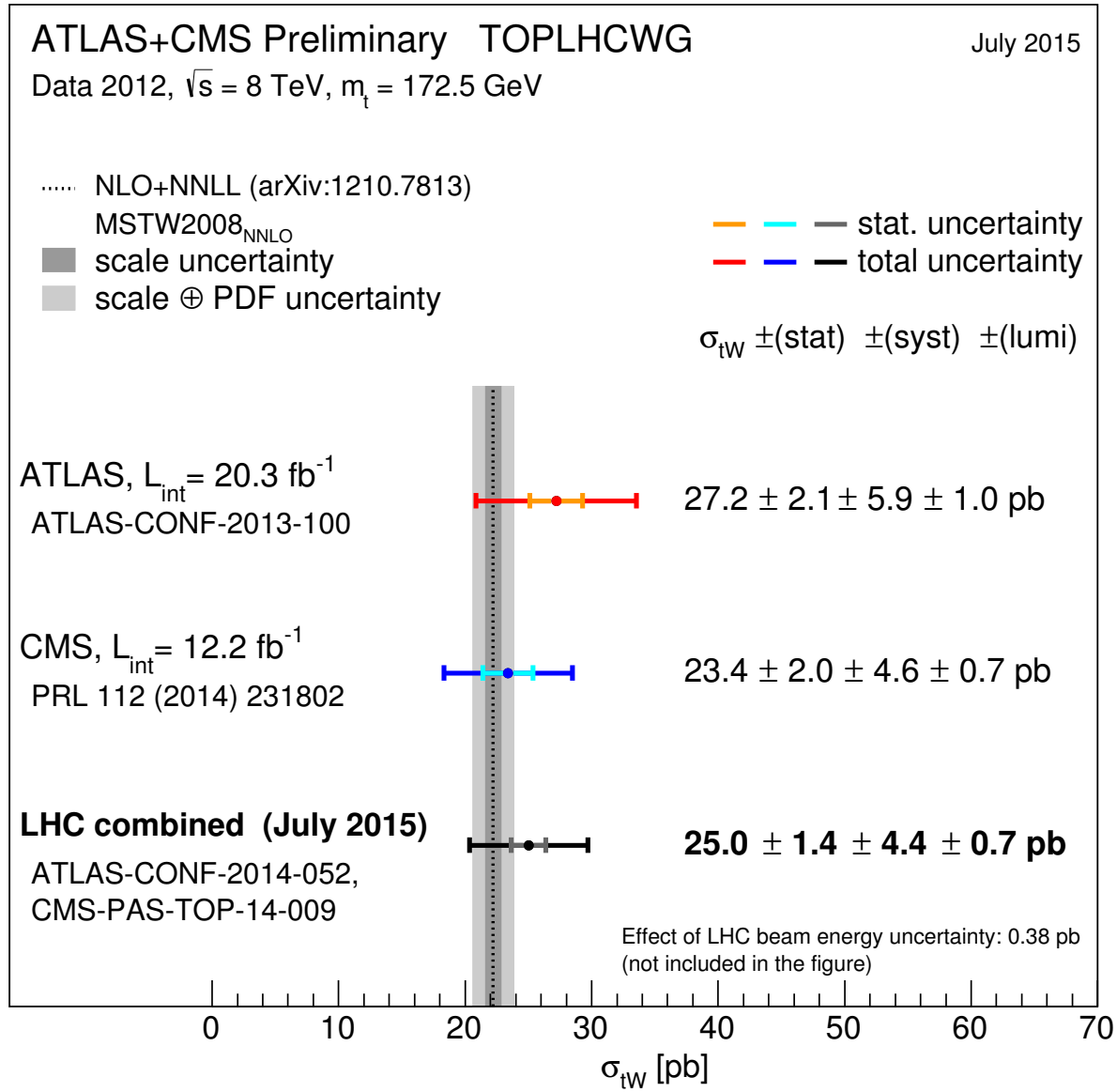
Wt cross-section combination

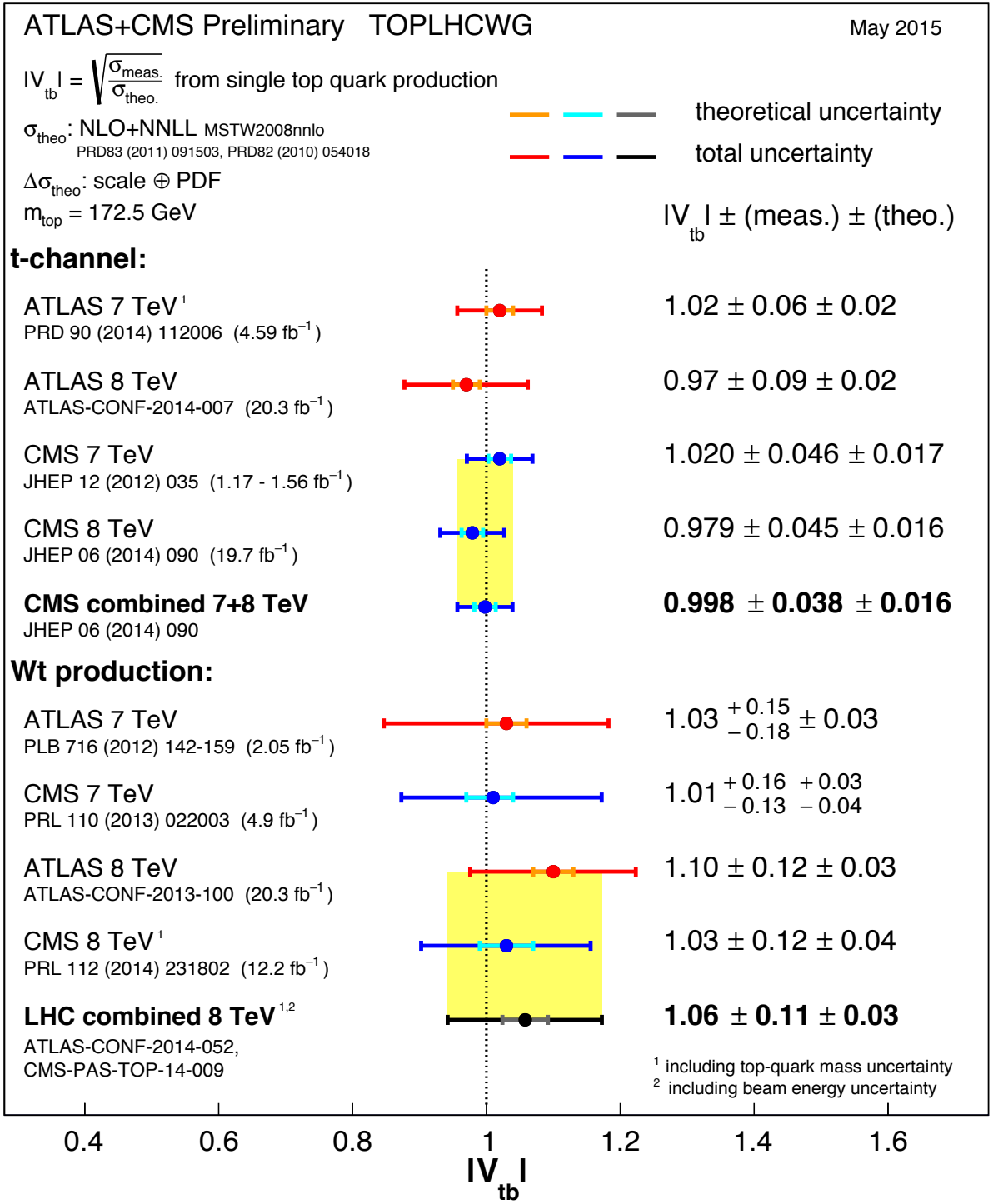
- BLUE combination
- study correlation of systematic uncertainties

Uncertainty breakdown

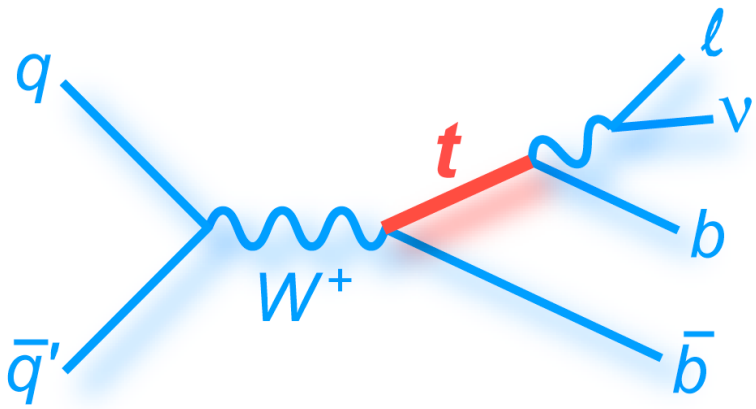
Data statistics	5.5%
Simulation statistics	1.8%
Luminosity	2.7%
Theory modeling	15.8%
Background normalization	2.3%
Jets	5.3%
Detector modeling	4.9%
Total systematics (excl. lumi)	17.5%
Total systematics (incl. lumi)	17.7%
Total uncertainty	18.6%



CKM matrix element V_{tb} from Wt production



s-channel production



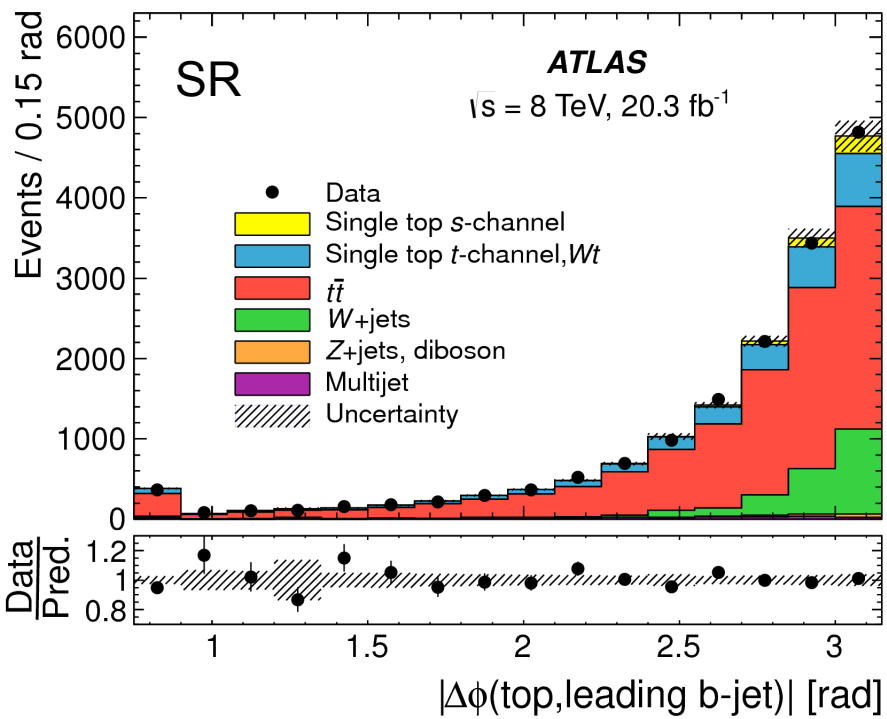
$\sigma = 5.6 \pm 0.2$ pb at 8 TeV

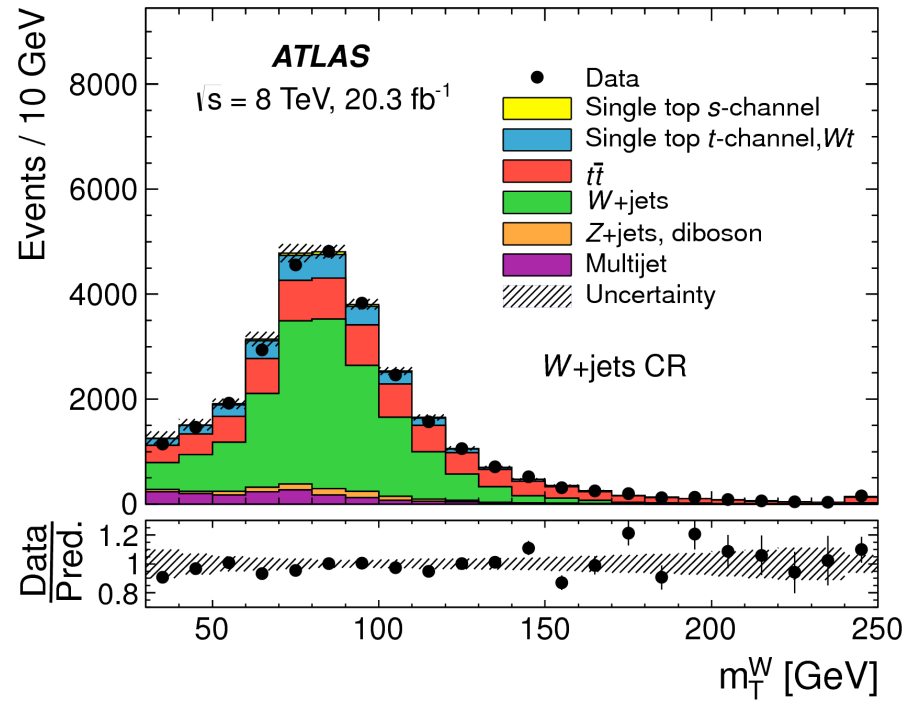
NLO+NNLL
Kidonakis, PRD81 054028 (2010)

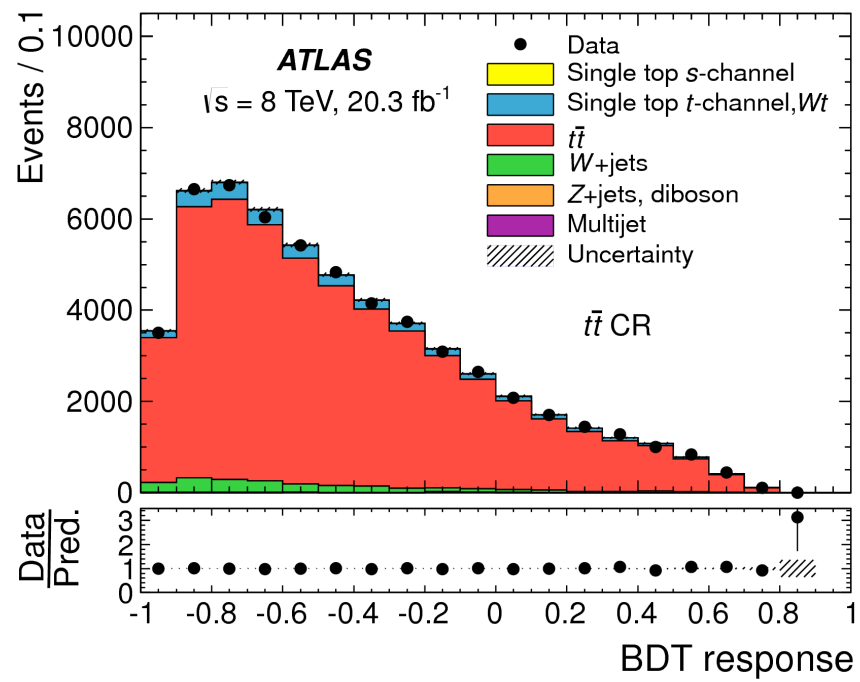
- Lepton+2 b-jet events
- Small signal, large backgrounds
- Main background contributions from
  - Top-quark pair production
  - Single top t-channel
  - W+bb
- Isolate s-channel signal through MVA

ATLAS s-channel

- Select lepton+2 b-jet events
- Control regions
  - W+jets
  - Top-quark pairs
- BDT to separate s-channel from backgrounds







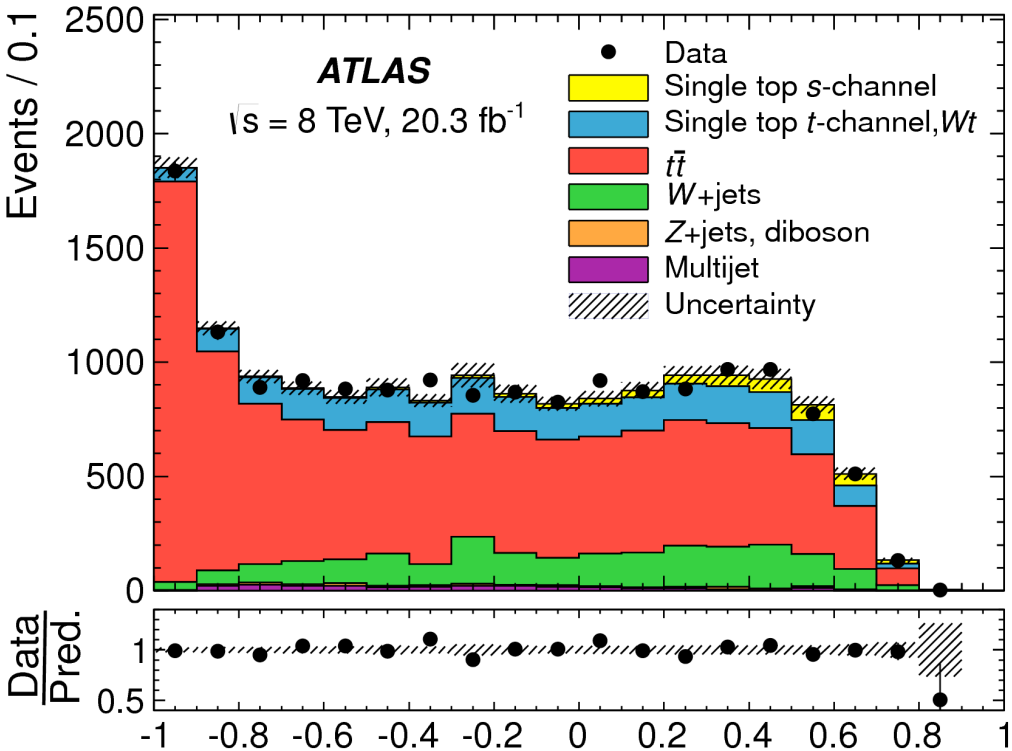
PLB 740 (2015) 118

ATLAS s-channel

- Fit to BDT distribution
- σ_{meas} = 5.0 ± 4.3 pb
- 1.3 s.d. significance
- 95% CL cross-section limit: 14.6 pb

Largest Uncertainties

Source	$\Delta\sigma/\sigma$ [%]
Data statistics	±35
Simulation statistics	±29
E_T^{miss} scale	±54
Jet energy scale	±39
Total systematic	±80
Total	±87



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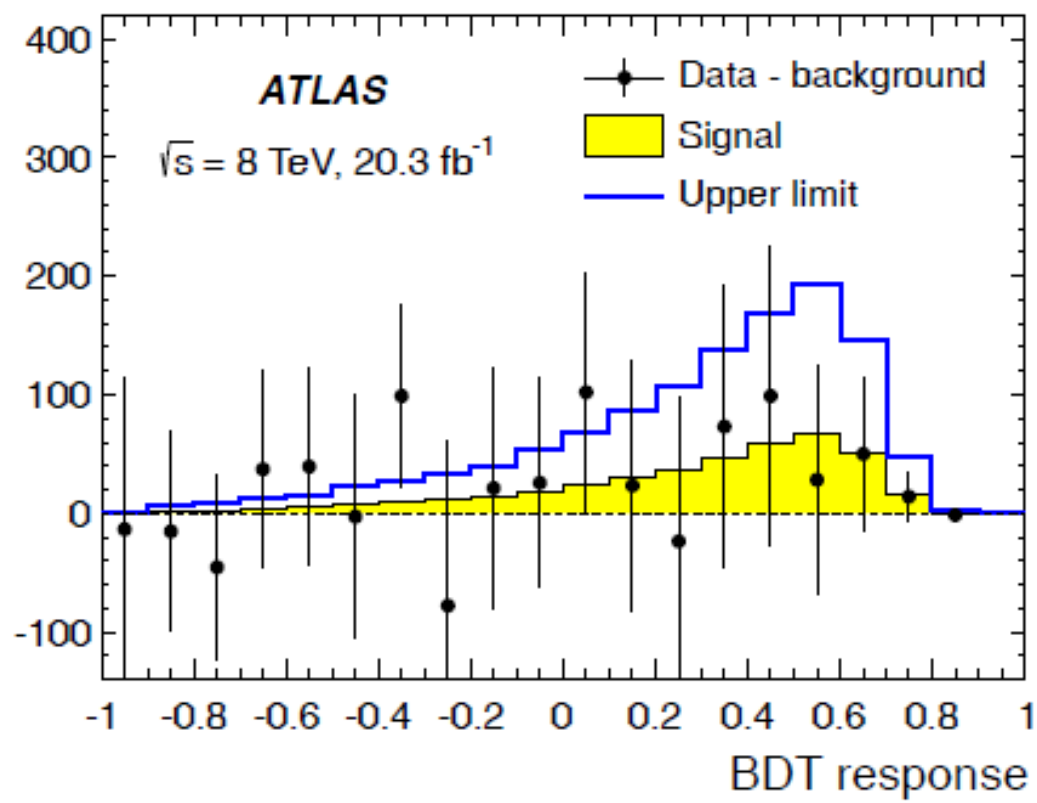
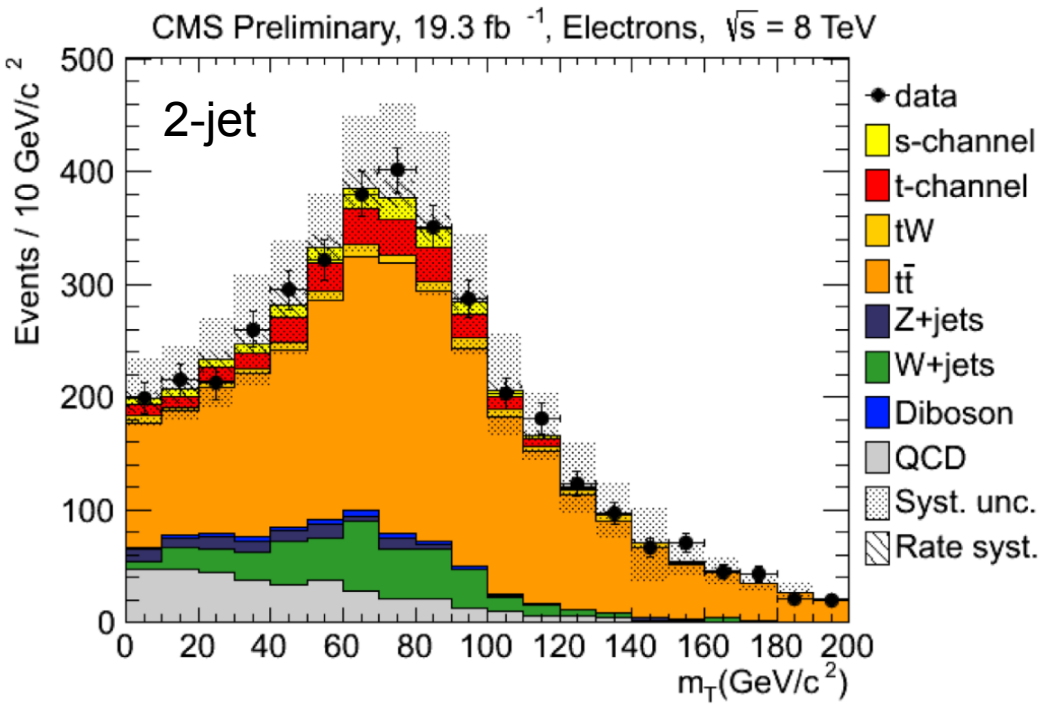
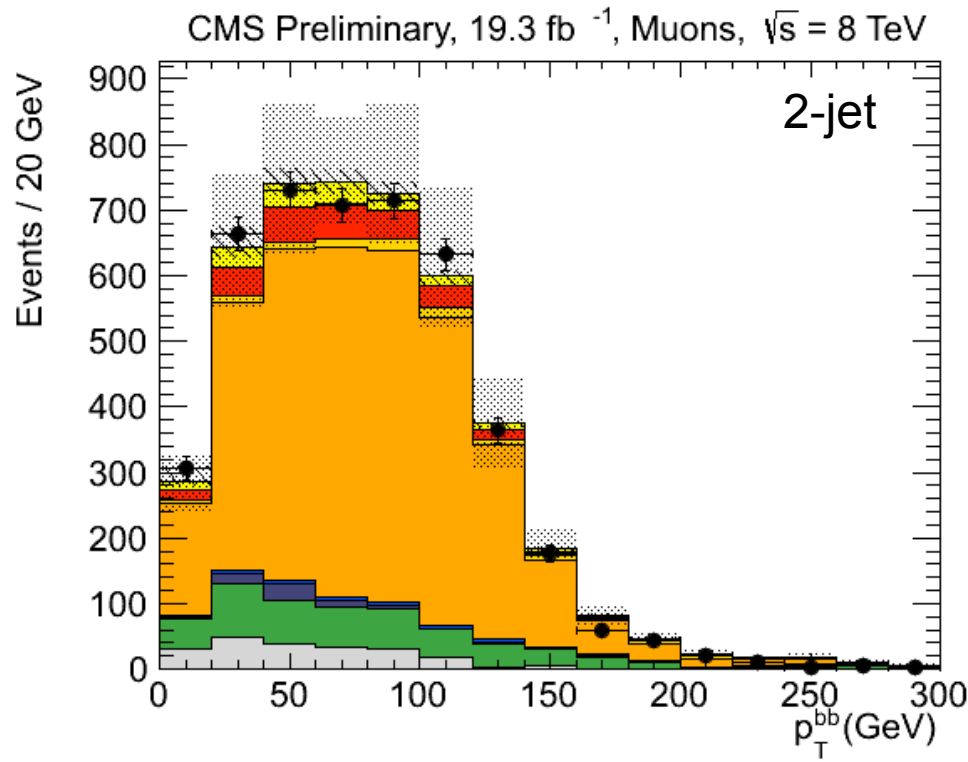


CMS s-channel

- Analyze electron and muon events separately
- Train BDTs in 2-jet, 2-tag and 3-jet, 2-tag
  - s-channel vs rest in 2-jet, 2-tag
  - Top-quark pairs vs rest in 3-jet, 2-tag
- Large systematic uncertainties
  - Theory modeling (scales, ME-PS)
  - JES, JER, E_T^{miss}





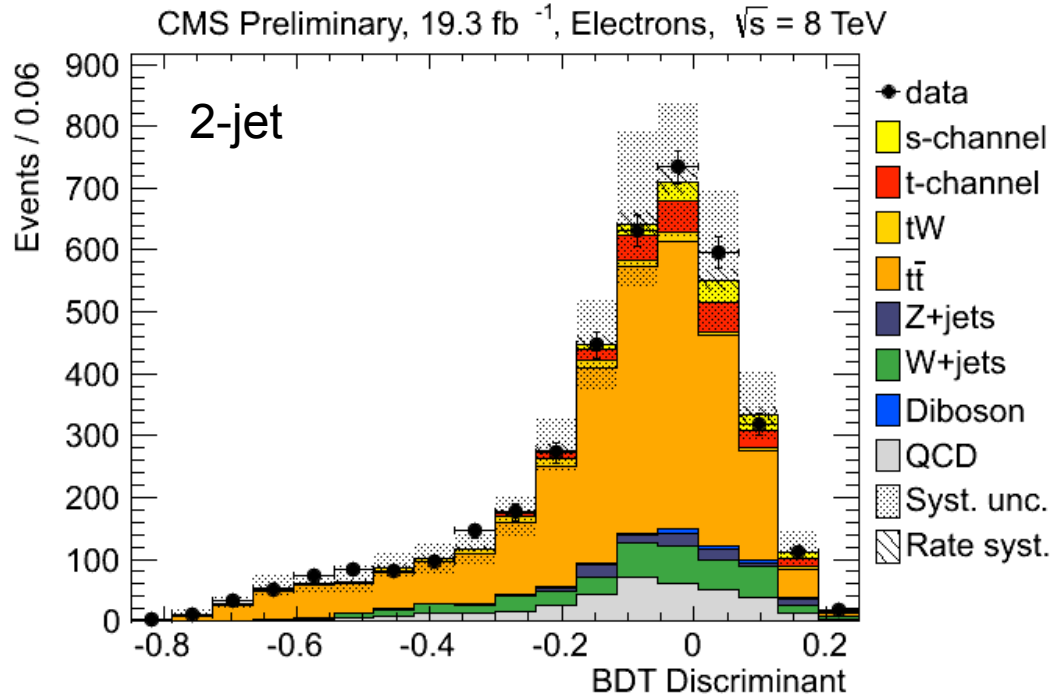
CMS PAS TOP-13-009

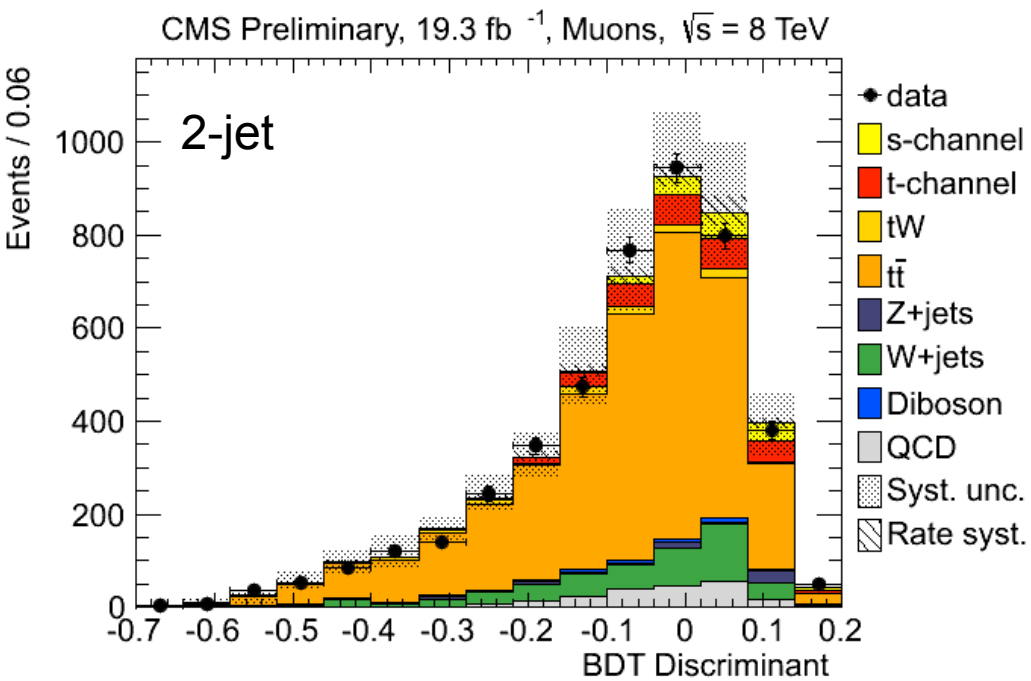
CMS s-channel

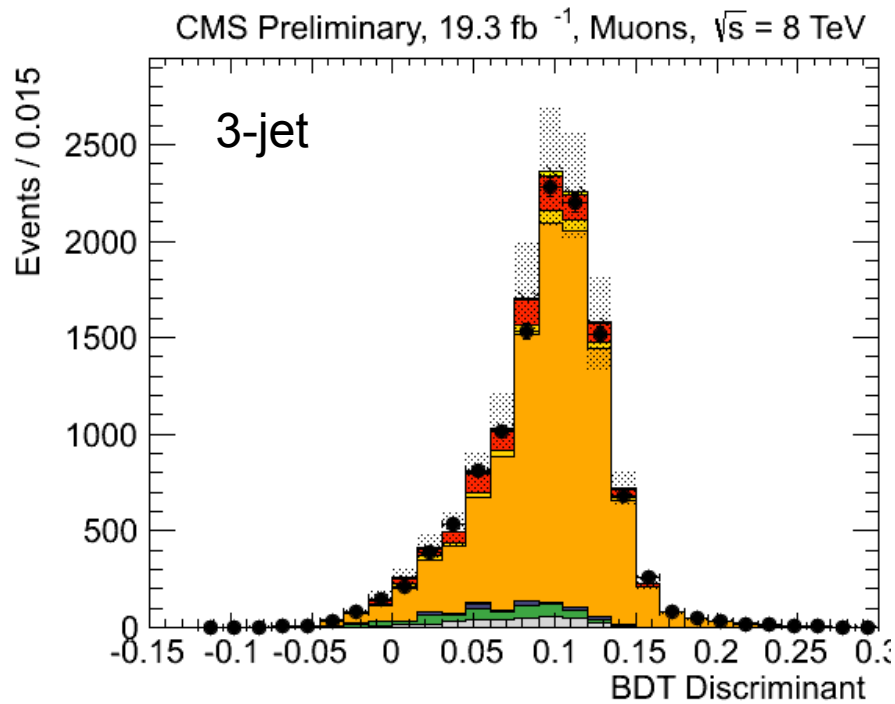
- Likelihood fit to BDTs
- Cross-section

$$\sigma_{s\text{-ch.}} = 6.2^{+8.0}_{-5.1}\ \text{pb}$$

  - 130% relative uncertainty
- 0.7 s.d. significance
- 95% CL cross-section limit: 11.5 pb

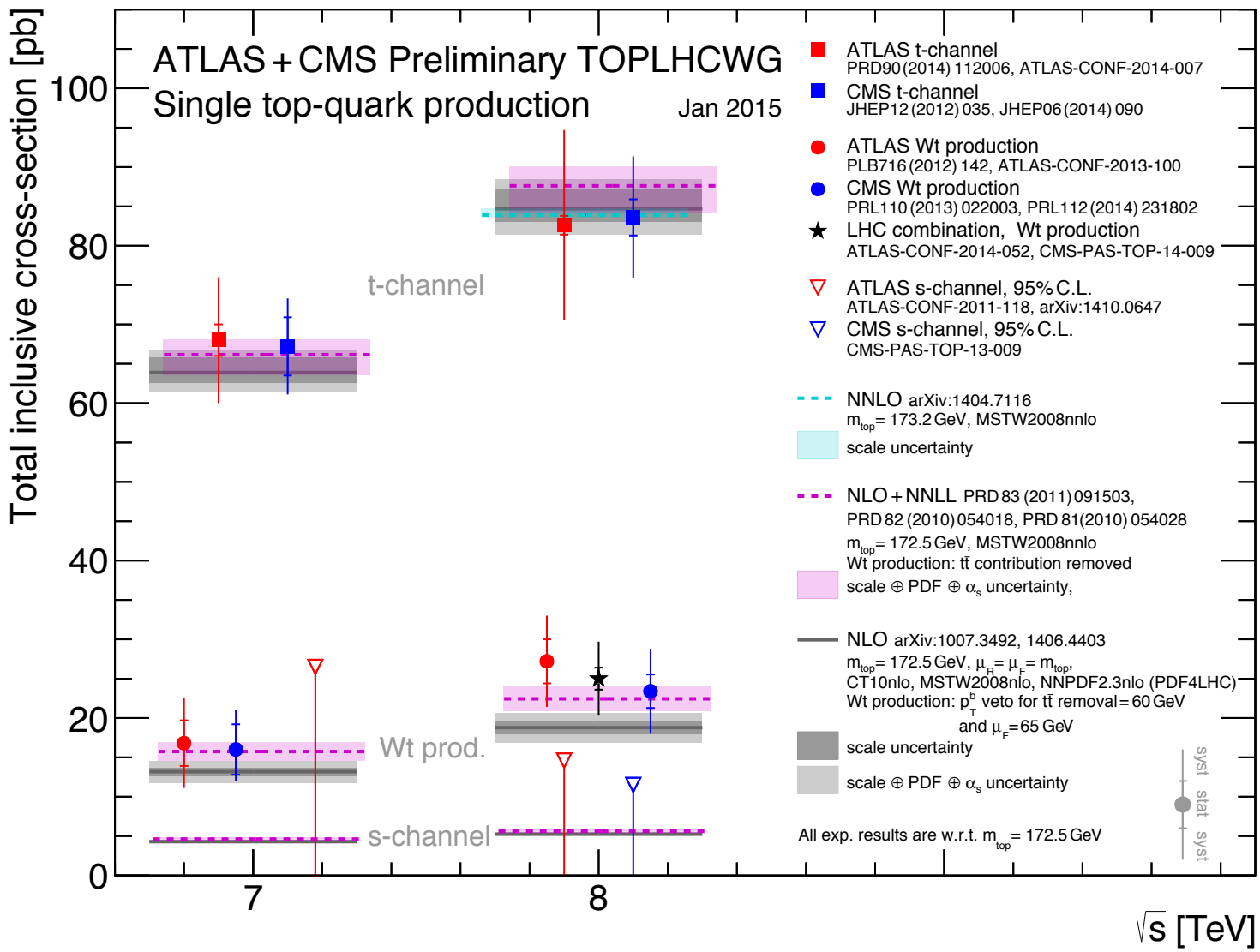




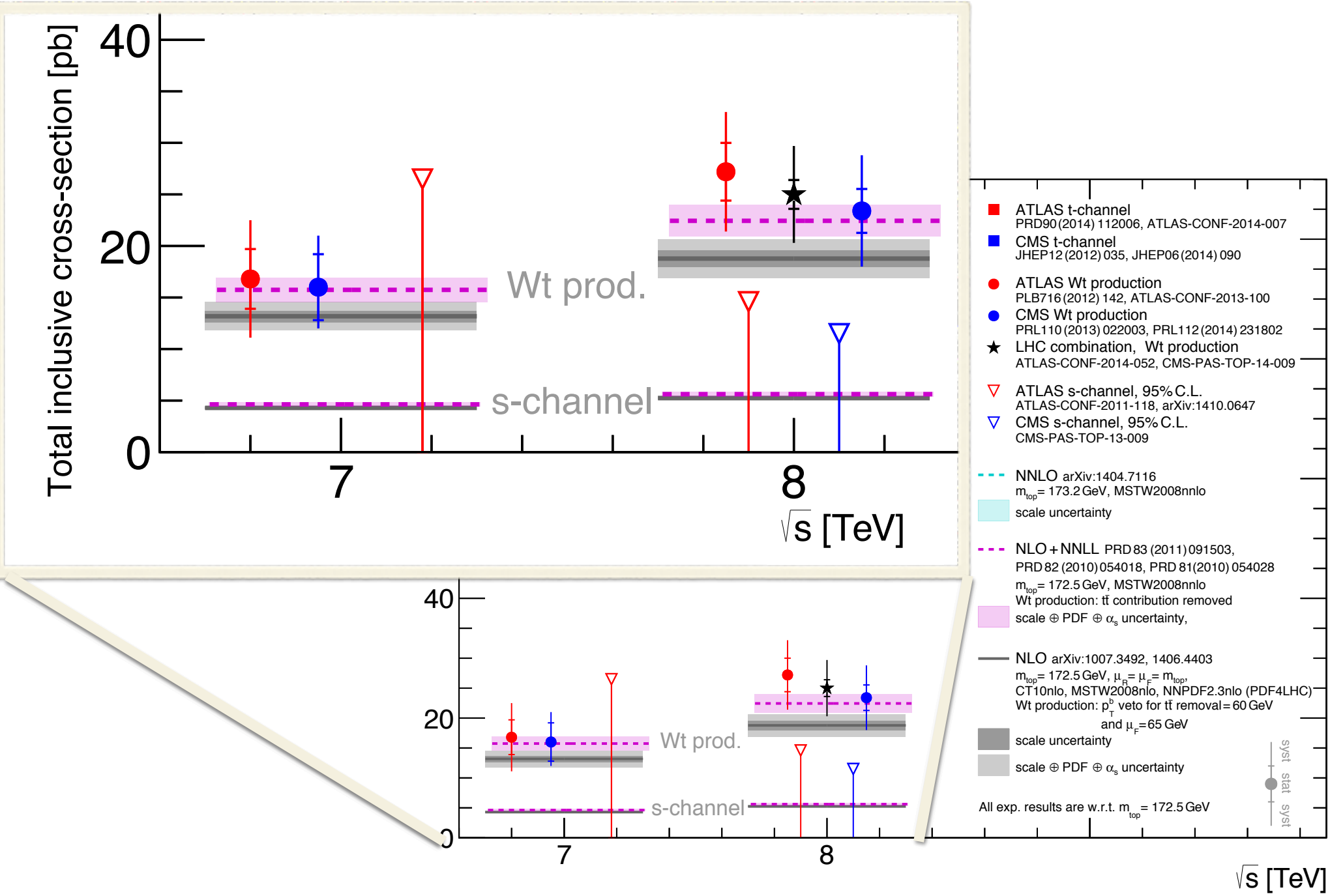


CMS PAS TOP-13-009

Summary of single top-quark measurements



Summary of single top-quark measurements



Prospects for Run II

- Wt associated production:
  - Larger top-quark pair background
  - Improved theory modeling
  - Re-establish at 13 TeV
  - Differential distributions
  - Observe in lepton+jets?
  - Boosted topology

	13/8 TeV
t-channel	2.6
Wt-channel	3.2
s-channel	2.0
$t\bar{t}$	3.3

- s-channel production:
  - Evidence or observation with large Run II samples
  - Requires a lot more data
  - Requires detailed understanding of theory and detector modeling uncertainties

Conclusions

- Single top-quark production has been observed in association with a W boson by CMS
  - ~19% uncertainty in LHC combination
  - Evidence at 7 TeV by ATLAS and CMS
- Single top-quark production in the s-channel has not yet been observed at the LHC
  - Measurement with 80% uncertainty
- Final 8 TeV papers now in preparation
- All single top-quark processes will be measured in Run 2
  - Larger statistics but worse S/B
  - Improved theory modeling based on Run 1 experience