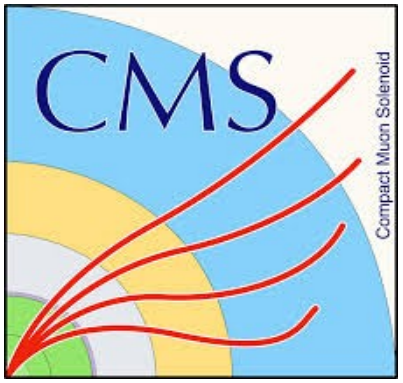


Single top plans for combinations

A. Jafari, O. Iorio, R. Schwienhorst

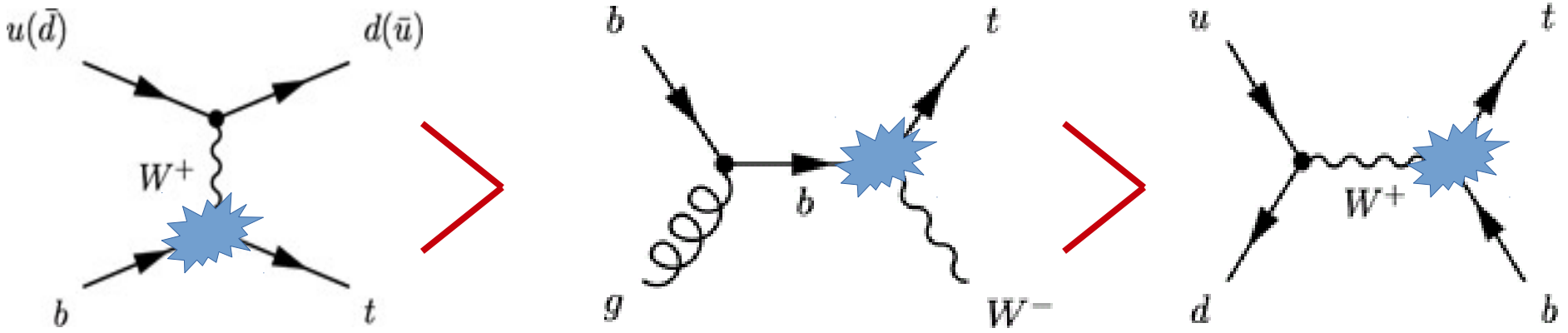
LHC Top WG Open Meeting
19 – 20 November 2015

Outline

- Introduction
- Possibilities for cross section combinations
  - *t*-channel
  - tW
  - *s*-channel
- Combination of the V_{tb} CKM matrix element

Single-top, what and why?

Top quark production at LHC
Dominant: in pair via QCD
Sub-dominant: singly through EWK



***t*-channel** **tW** ***s*-channel**

Single-top is sensitive to new physics
- FCNC, anomalous tWb couplings
- New particles, W', $H^{\pm}$

Background in searches
- Higgs, SUSY

Characteristic scenario for SM measurements
- Top polarization, W helicity, top mass, $|V_{tb}|$

Single-top, what and why?

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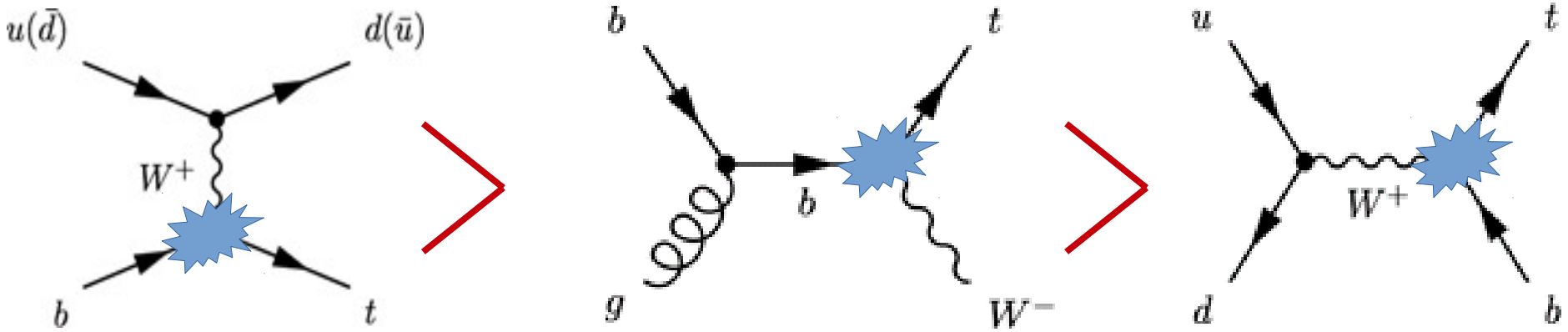

***t*-channel** **tW** ***s*-channel**

7 TeV (pb)	63.9 ± 2.7	15.7 ± 1.2	4.29 ± 0.18
8 TeV (pb)	84.7 ± 3.5	22.4 ± 1.5	5.24 ± 0.21
13 TeV (pb)	217 ± 8.4	71.7 ± 3.9	10.32 ± 0.38

NLO theory calculations (scale+PDF+α_s)

Single-top, what and why?

Top quark production at LHC
Dominant: in pair via QCD
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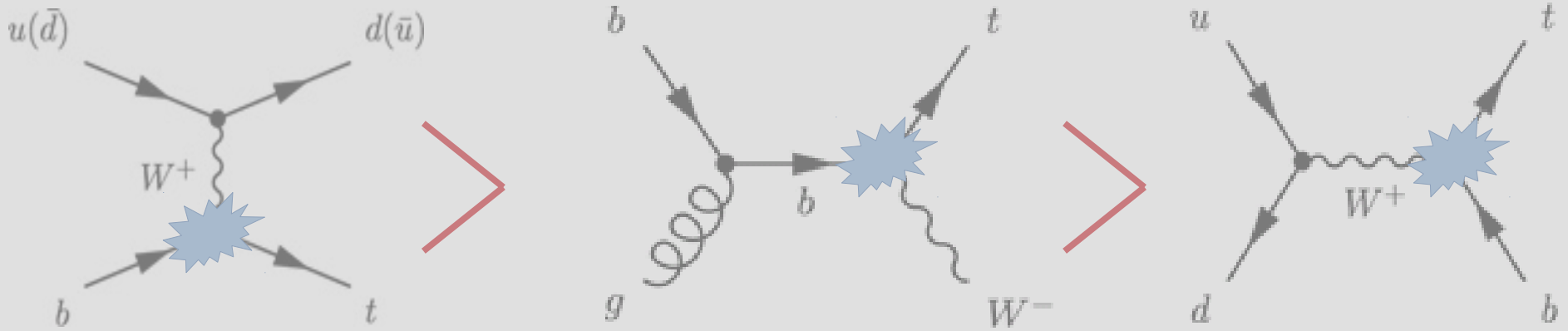

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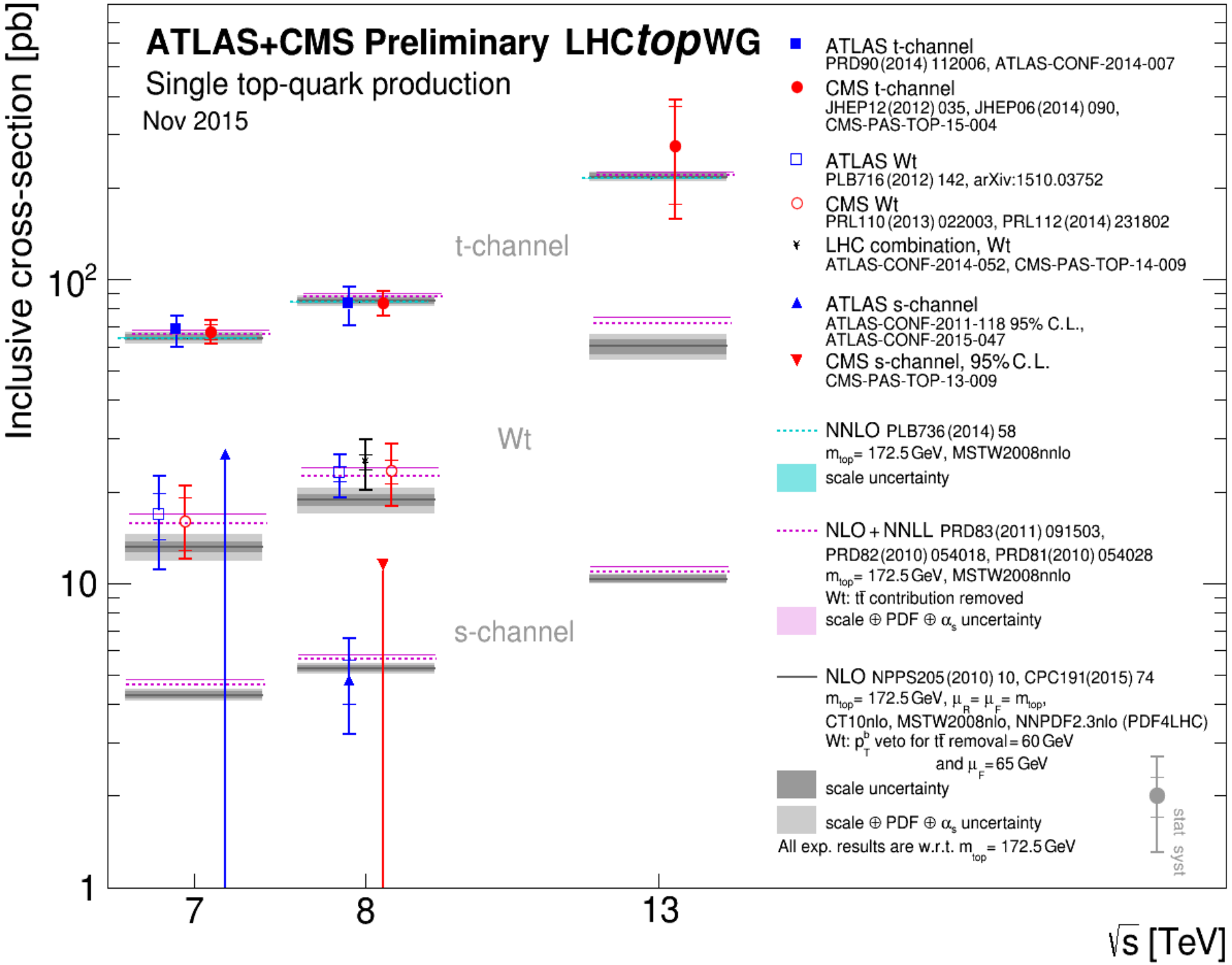
Detailed studies | Observation | Evidence

NLO theory calculations (scale+PDF+α_s)

LHC Single-top cross sections



t-channel: *detailed studies*

Cross section

- Precise in the full phase space
- Comparison with theory in the fiducial volume
  - Validate and compare different models
- Extracting the CKM matrix element $|V_{tb}|$

Covered here …

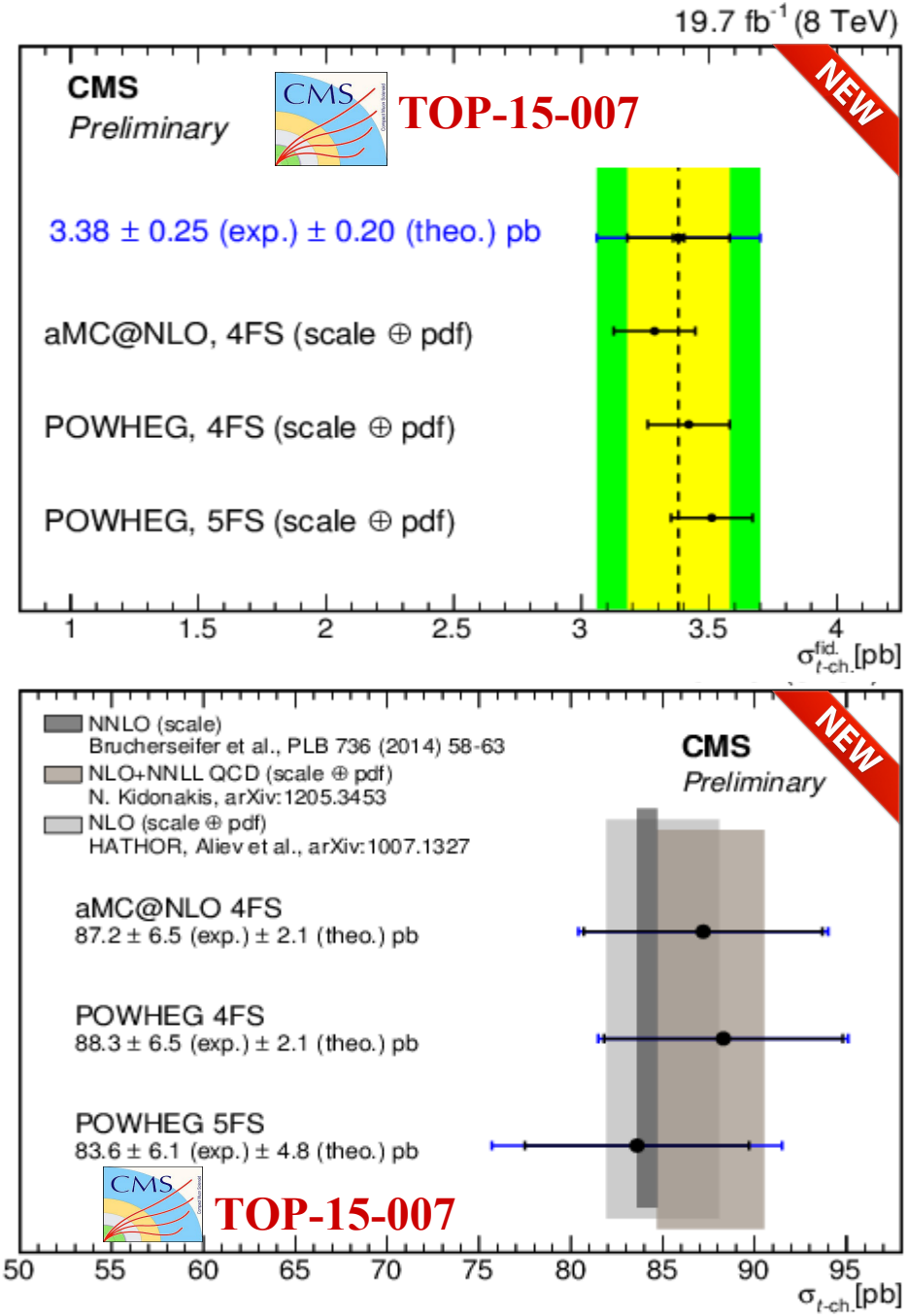
Other properties

- Precise measurements of angular properties
- Sensitive to tWb anomalous couplings

See the talk by Nuno Castro for ideas on combinations …

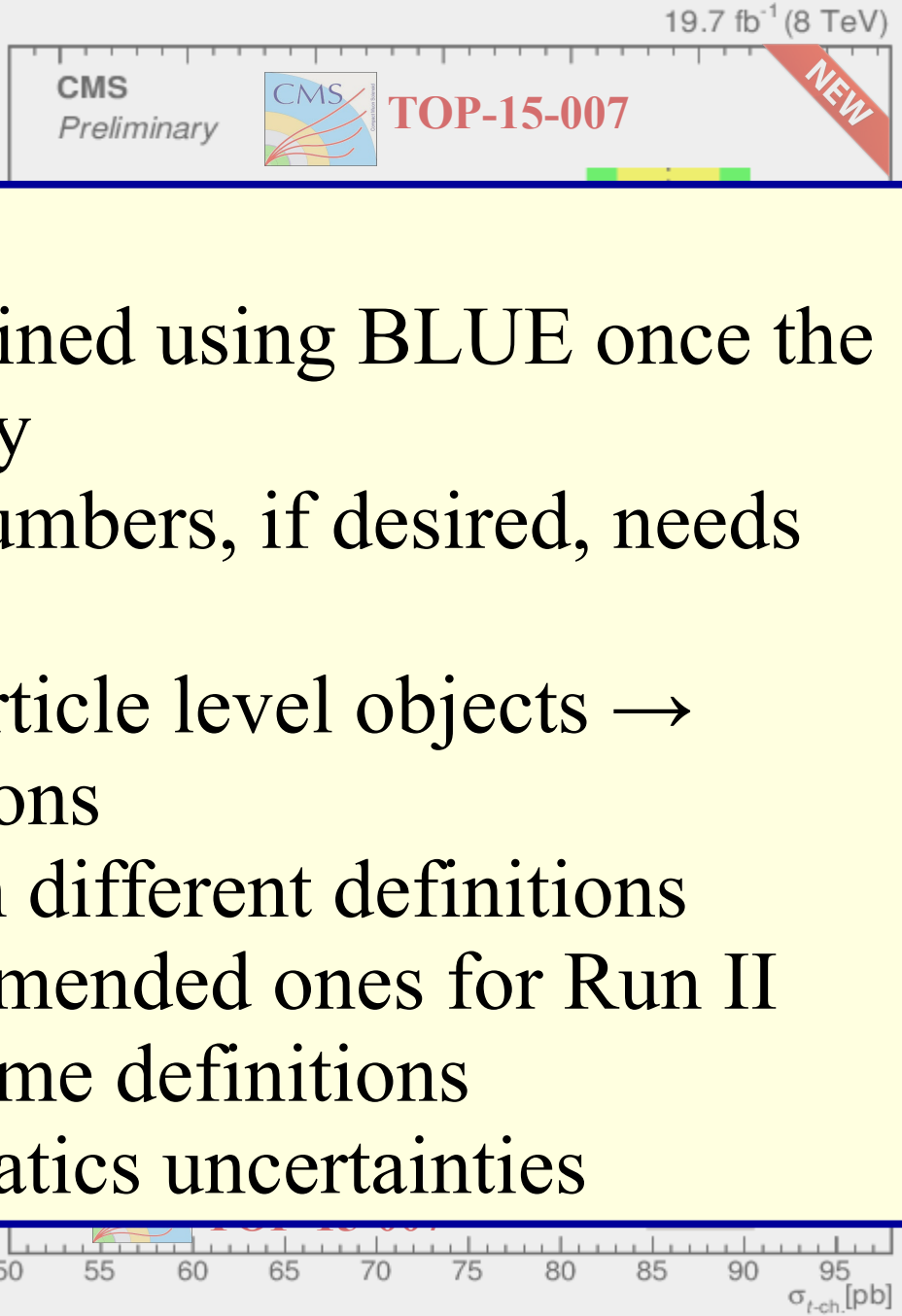
t-channel: $\sigma_{\text{t-ch}}$ *in fiducial volume*

- Based on **JHEP 06 (2014) 090**
- First look into 4FS vs. 5FS modeling
- For fiducial measurement
  - Particle level definitions along with LHC*top*WG recommendations
- Corresponding analysis in ATLAS is **ATLAS-CONF-2014-007**
- Paper in preparation



t-channel: $\sigma_{\text{t-ch}}$ *in fiducial volume*

- Based on JHEP 06 (2014) 090



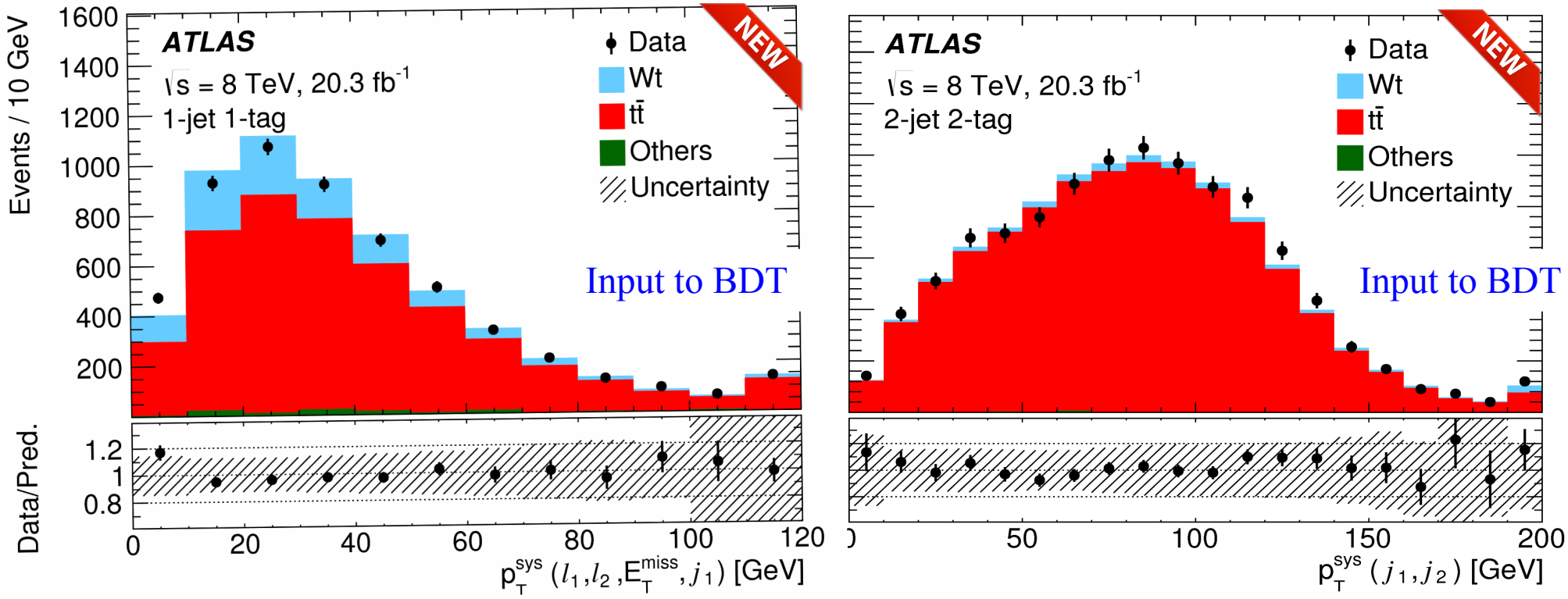
Combination plan:

- *Inclusive* measurements combined using BLUE once the corresponding papers are ready
- Combination of the fiducial numbers, if desired, needs more effort:
  - Common definitions for particle level objects → LHC*top*WG recommendations
    - See backup for details on different definitions
    - Aiming to use the recommended ones for Run II
  - Differences in fiducial volume definitions
  - Refining the related systematics uncertainties

tW: *new ATLAS result, 7.7σ significance*

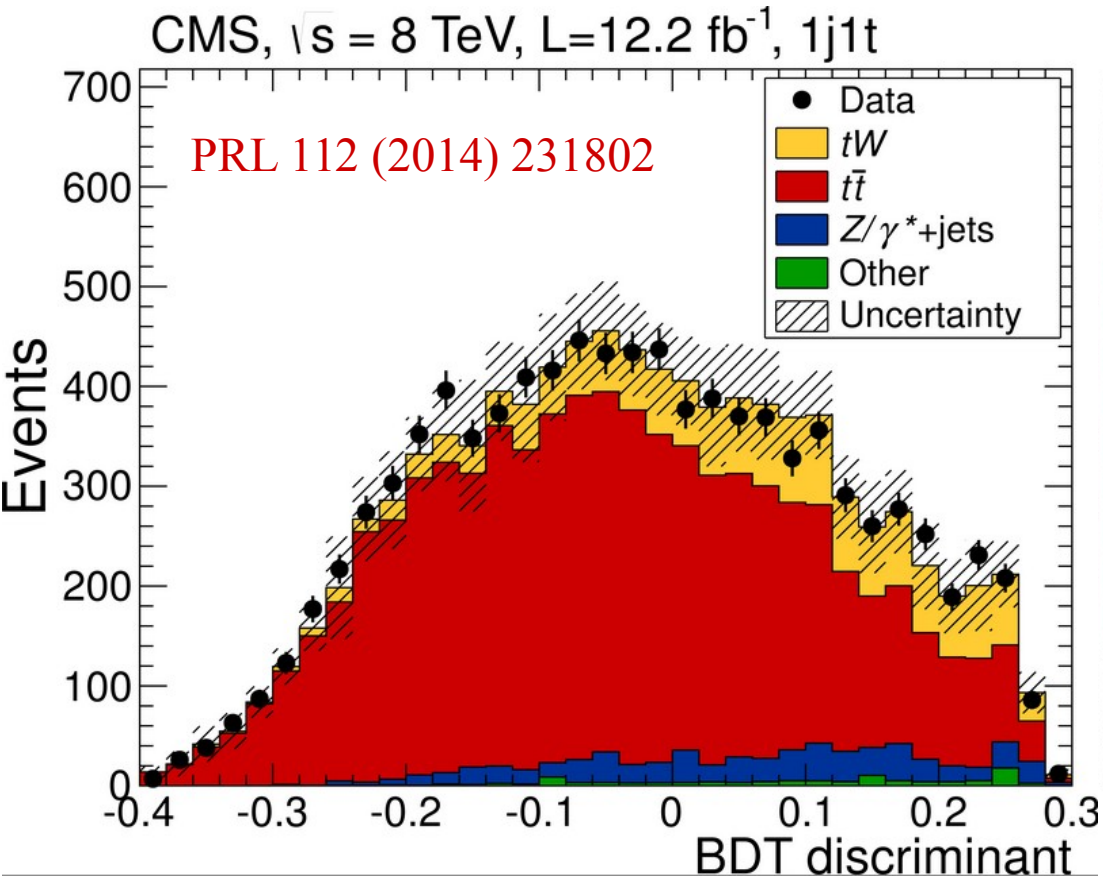
- ATLAS has also observed the tW at 8 TeV
  - Simultaneous fit on BDT output in multiple regions with different jet and b-jet multiplicities

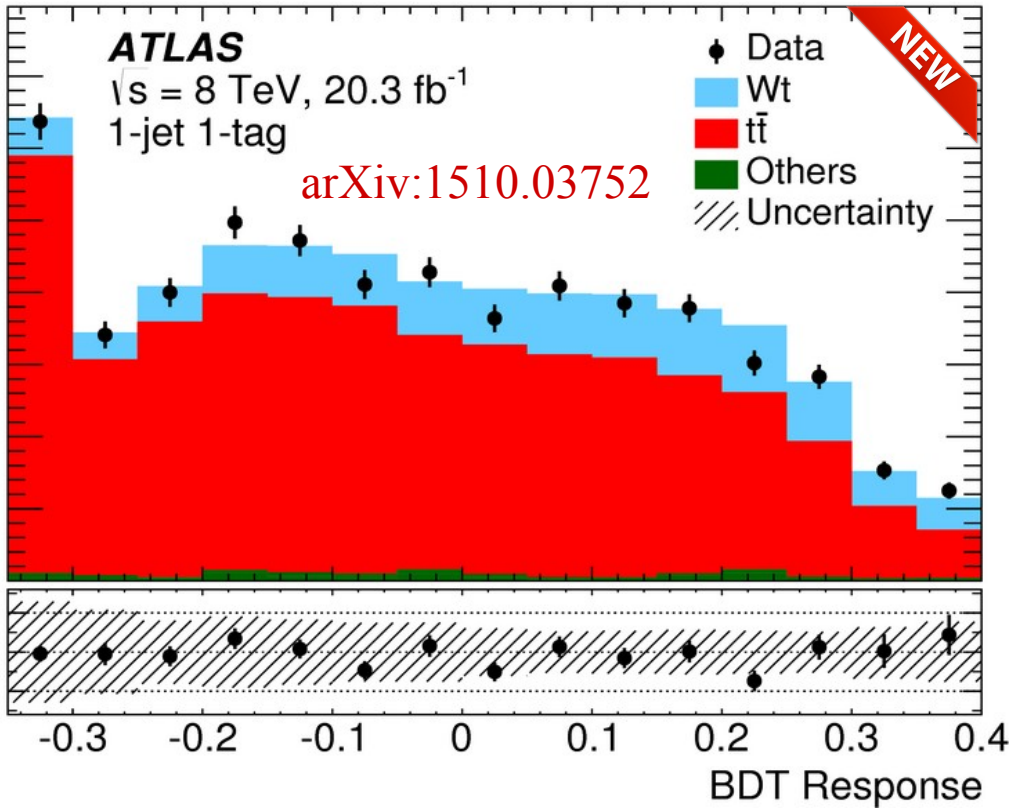
arXiv:1510.03752



  - Follows the latest LHC*top*WG recommendations for systematics
  - Measurement also in the fiducial volume

tW: *Observed in both experiments*



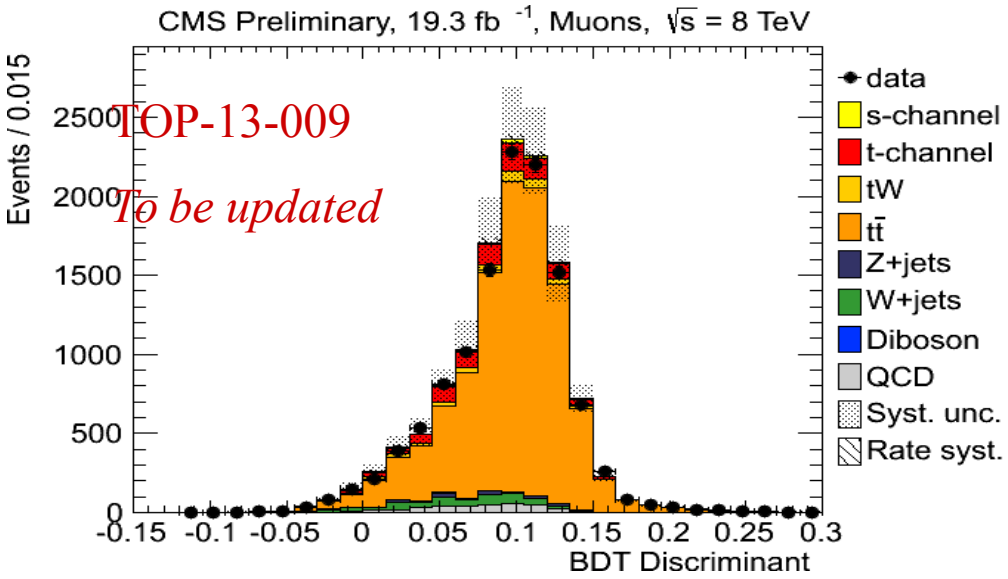


Combination of the cross sections:

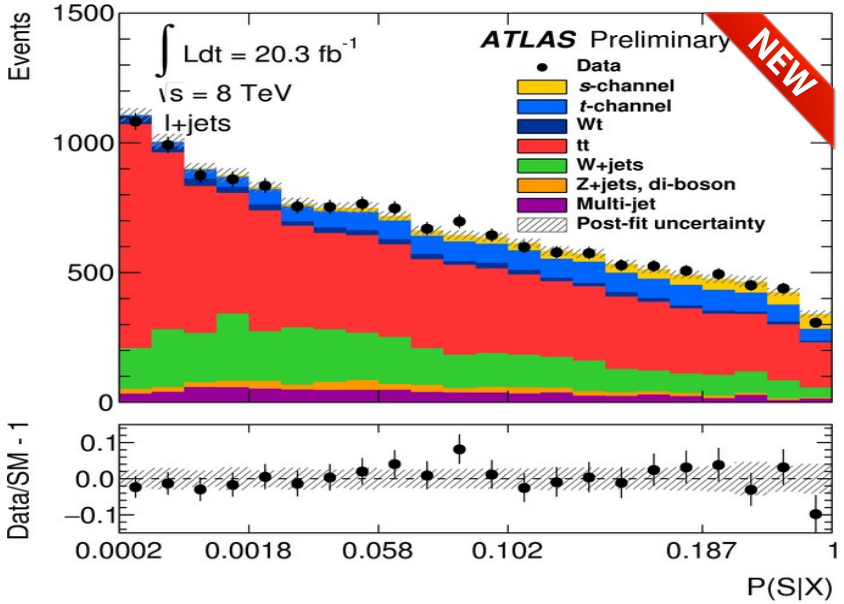
- With the CMS observation paper, using BLUE
- Work has already started to understand the correlations with ATLAS new systematic treatment

s-channel: *evidence seen by ATLAS*

- ATLAS has seen an evidence recently
- Update from CMS is expected soon



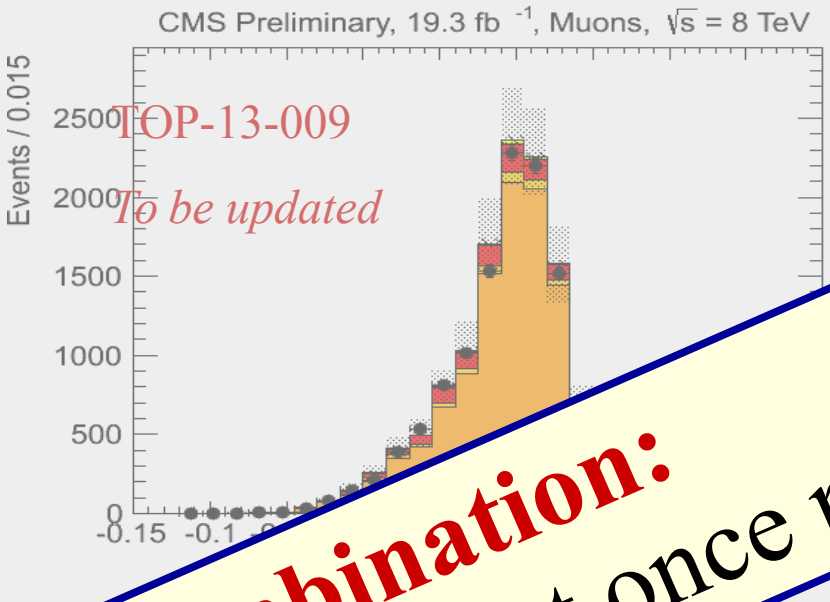
ATLAS-CONF-2015-047

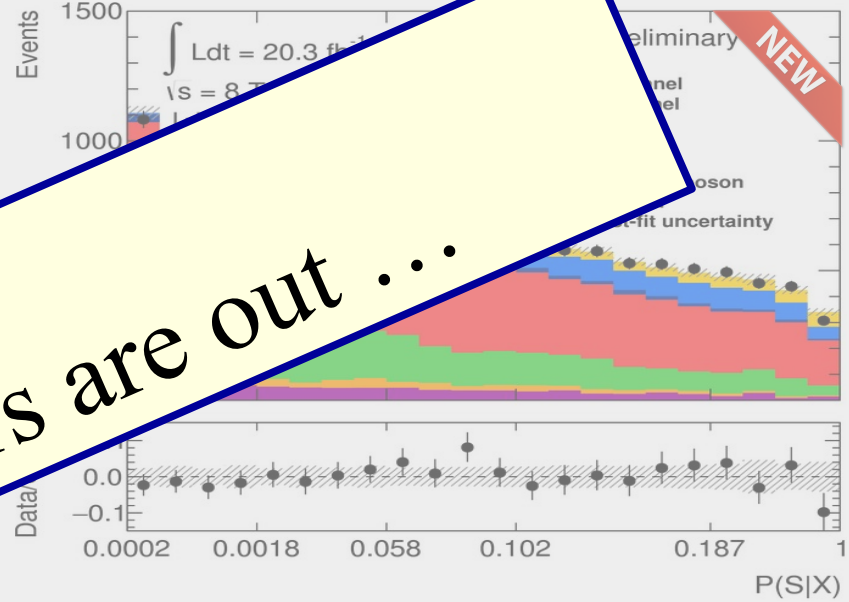


- Better significance and cross section measurement is expected from combination
- How to handle different systematic/statistical treatments?
  - Combining likelihoods? Different statistical frameworks ...
  - Marginalization of different systematics can lead to different significances

s-channel: *evidence seen by ATLAS*

- ATLAS has seen an evidence recently
- Update from CMS is expected soon

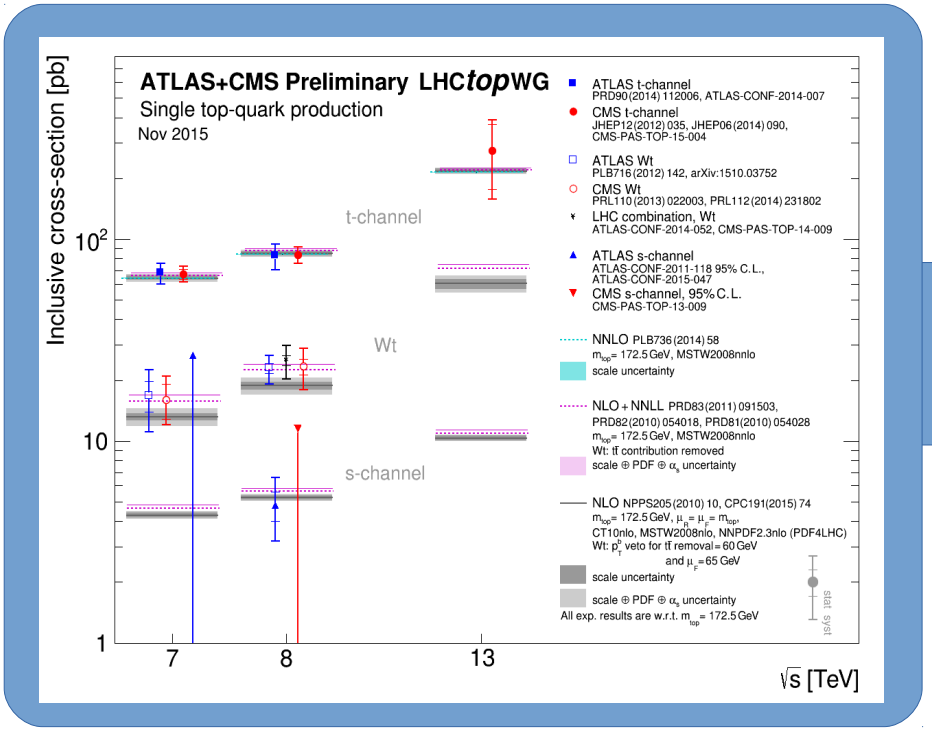




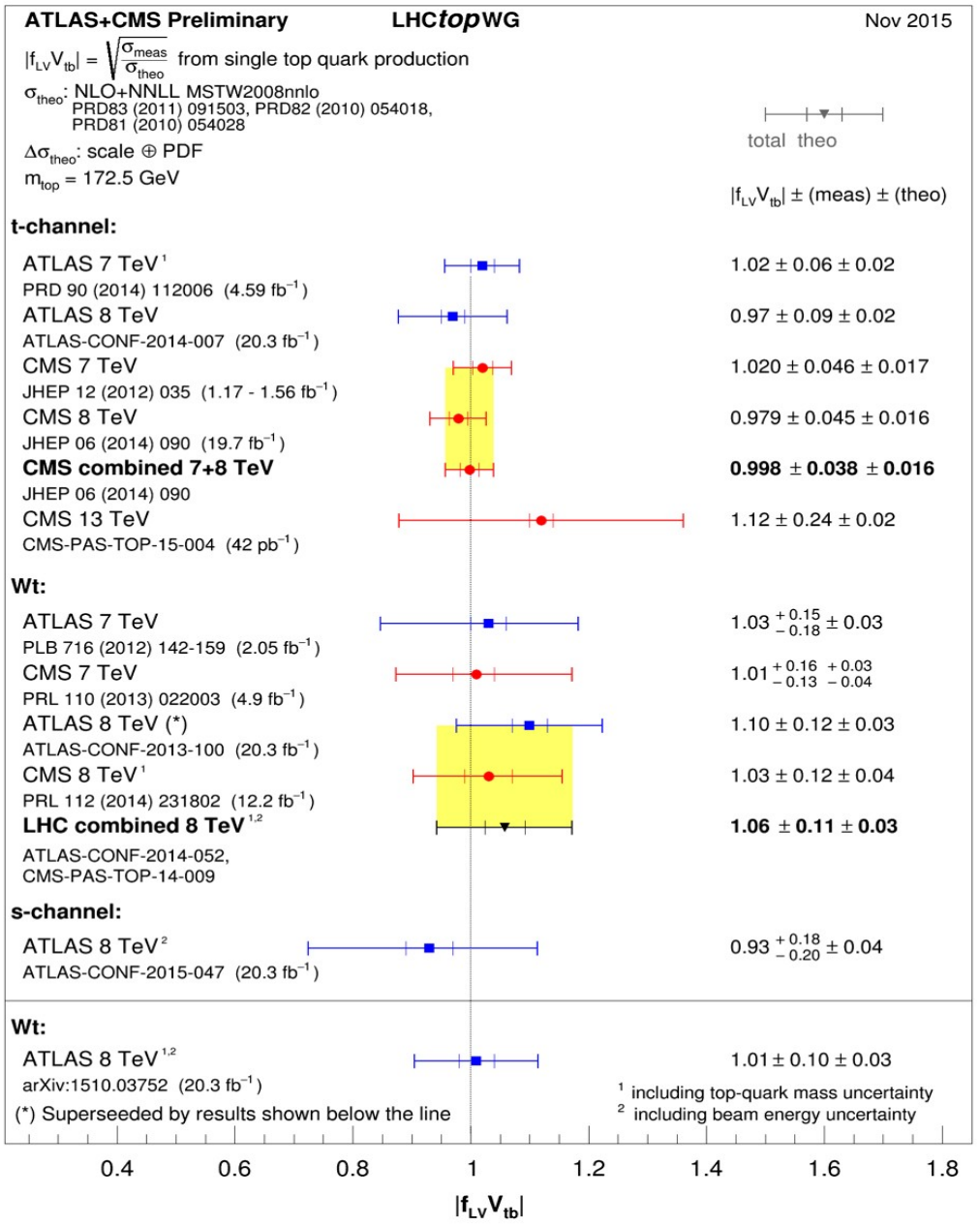
Combination:
- Will start once papers are out …

- Be… cross section measurement is expected from com…
- How … handle different systematic/statistical treatments?
  - Combining likelihoods? Different statistical frameworks ...
  - Marginalization of different systematics can lead to different significances

Vtb from single-top



$$|V_{tb}| = \sqrt{\frac{\sigma_{exp.}}{\sigma_{theo.}}}$$



Vtb: *assumptions and alternatives*

$$|V_{tb}| = \sqrt{\frac{\sigma_{exp.}}{\sigma_{theo.}}}$$

$$|V_{tb}| \gg |V_{td}|, |V_{ts}|$$

- Assuming top quarks decay only to Wb
  - Neglecting V_{td}, V_{ts} in the production
- Not sensitive to couplings with different kinematics
- Alternative methods are possible (see e.g. here)
  - Involving e.g R = BR(t→bW)/BR(t→qW) from ttbar
- Combination becomes complicated + other ingredients are needed → start with the simplest method
- Intend to use BLUE to combine $|V_{tb}|^2$

Vtb: *ingredients for the uncertainty*

$$|V_{tb}| = \sqrt{\frac{\sigma_{exp.}}{\sigma_{theo.}}} \quad \Rightarrow \quad \Delta V_{tb} = \ldots$$

σ_{exp}: all single-top channels measurements could go in

– Expect dominant contribution from *t*-channel

$\sigma_{theo.}$: theory uncertainty is not negligible

– *Which theory cross-section for t-channel?*
The most precise (NNLO) or the NLO with all needed uncertainties available?

– *What uncertainties to add?*
PDF, Scale, top mass, collider energy, b-mass?

Vtb: *steps for the combination*

Agree on few items

- What cross section to use
- What uncertainties? Top and bottom quark mass? ...

Consider all channels (even cross energy)

- Less precise results would have less impact

Consider other methods

- Once the previous step is established
- Expand the interpretation: carefully add R in the measurement?

Conclusions

- Combination of single-top cross sections and V_{tb} still has some road ahead
- *t*-channel combination is waiting for a few updates from the experiments
- tW combination has already started
- *s*-channel combination is waiting for updates from the experiments, will need also some aligning of uncertainties/statistical methods used.
- V_{tb} combination can be straightforward as a first step, and then get increasingly more complicated by adding in more channels and different assumptions

BACKUP

CMS vs. ATLAS in fiducial *t*-channel

Leptons:

CMS & ATLAS: dressed leptons (LHCtopWG) from W decay

MET:

CMS: does not use particle-level MET

ATLAS: vector sum of all neutrino's from W in the event

Jet:

CMS & ATLAS: clustering all particles but prompt lepton/photon/neutrino with anti-kT algo.

B-tagging:

CMS: ghost matching

ATLAS: B-hadron matching (not clear to me how)

CMS vs. ATLAS in fiducial *t*-channel

Nominal results

Generated and extrapolated by aMCatNLO

CMS

Object	Kinematic cuts at detector level	Cuts at particle level	number required
Tight Muon	$p_T > 26$, $\|\eta\| < 2.1$, $I_{rel} < 0.12$	$p_T > 30$, $\|\eta\| < 2.4$	exactly 1 (or 1 Ele)
Tight Electron	$E_T > 30$, $\|\eta\| < 2.4$, $I_{rel} < 0.1$	$p_T > 30$, $\|\eta\| < 2.4$	exactly 1 (or 1 Mu)
Veto Muon	$p_T > 10$, $\|\eta\| < 2.4$, $I_{rel} < 0.2$	-	0
Veto Electron	$E_T > 20$, $\|\eta\| < 2.4$, $I_{rel} < 0.15$	-	0
Jets	$p_T > 40$, $\|\eta\| < 4.7$	$p_T > 40$, $\|\eta\| < 5.0$	exactly 2
B-tagging	1 jet is tagged	$\|\eta\| < 2.4$, b-hadron	exactly 1
m_T (muons)	$m_T > 50$	-	-
$\not{E}_T$ (electrons)	$\not{E}_T > 45$	-	-

ATLAS

Object	Cut
Electrons	$p_T > 25$ GeV and $\|\eta\| < 2.5$
Muons	$p_T > 25$ GeV and $\|\eta\| < 2.5$
Jets	$p_T > 30$ GeV and $\|\eta\| < 4.5$
	$p_T > 35$ GeV, if $2.75 < \|\eta\| < 3.5$
Lepton (ℓ), Jets (j_i)	$\Delta R(\ell, j_i) > 0.4$
E_T^{miss}	$E_T^{miss} > 30$ GeV
Transverse W-boson mass	$m_T(W) > 50$ GeV
Lepton (ℓ), jet with the highest p_T (j_1)	$p_T(\ell) > 40$ GeV $\left(1 - \frac{\pi - \lvert\Delta\phi(j_1,\ell)\rvert}{\pi - 1}\right)$

Nominal results

Generated by AcerMC ($\mu = m_t$)

Extrapolated by aMCatNLO

CMS vs. ATLAS in tW

Theory modeling uncertainties

	ATLAS	CMS
ISR/FSR	ISR/FSR for Wt and ttbar	Renormalization/ factorization scale for Wt and ttbar
Wt generator and PS	PowHeg, MC@NLO with Pythia, Herwig	
Ttbar generator and PS	PowHeg, MC@NLO with Pythia, Herwig	ME/PS matching threshold and scale variation
PDF	PDF4LHC	PDF4LHC
DR/DS	DR/DS	DR/DS

https://indico.cern.ch/event/340357/session/4/contribution/9/attachments/667587/917615/2015-01-12_Wt.pdf