Top quark: Production at ATLAS and CMS

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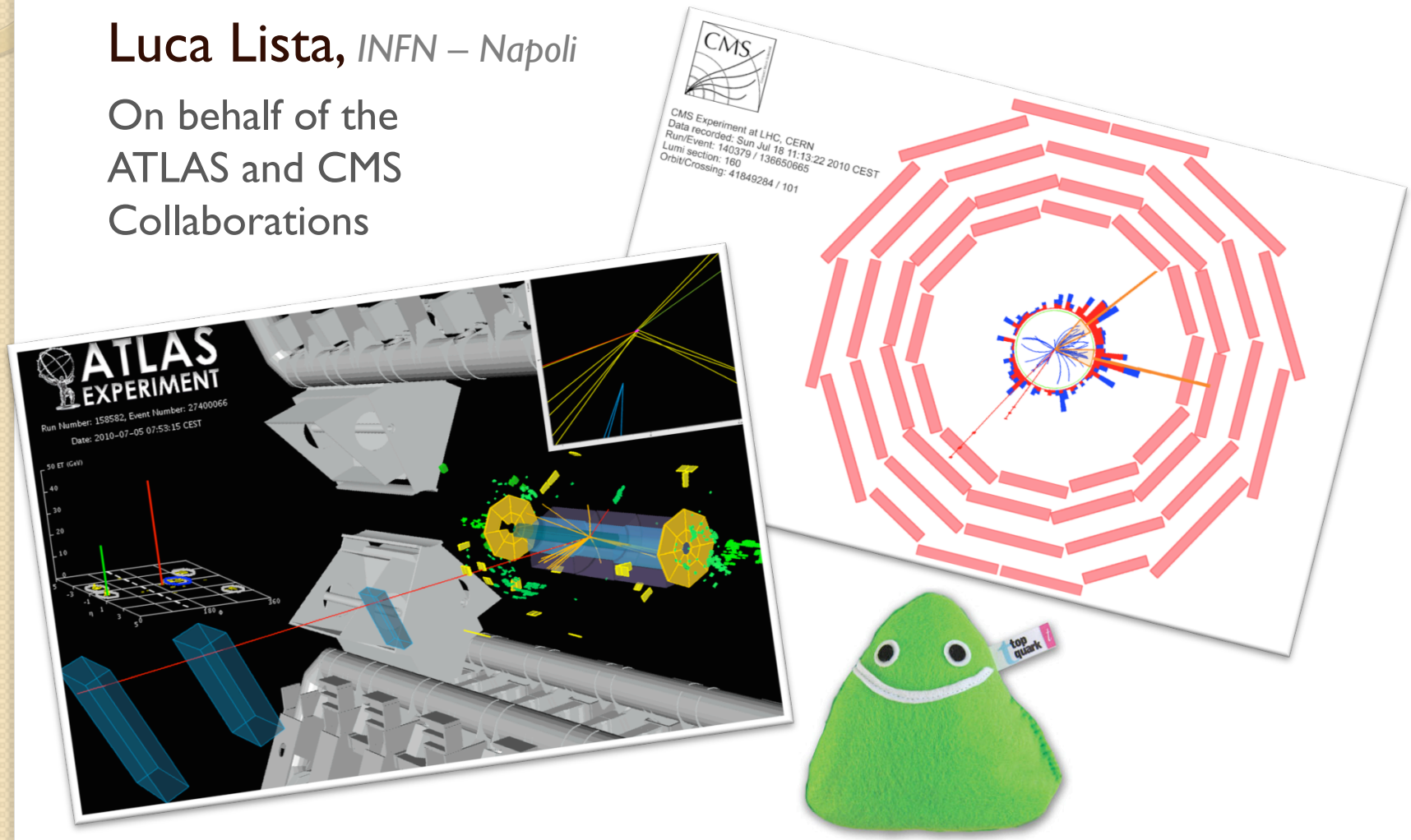
On behalf of the ATLAS and CMS Collaborations



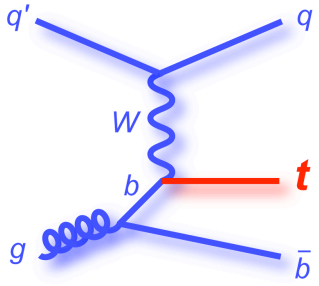
Rencontres de Moriond Electroweak Interactions and Unified Theories, La Thuile, 15-22 March 2014

Top production at LHC

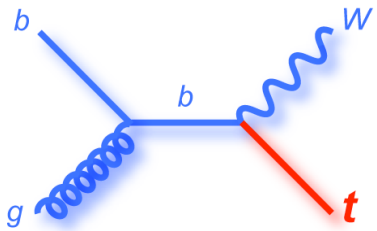
Czakon, et al..: PRL110(2013)252004
Cacciari et al.: PLB710,612 (2012)
Baernreuther et al.: PRL109,132001 (2012) Czakon, Mitov: arXiv:1207.0236 (2012), arXiv:1210.6832 (2012)
N. Kidonakis: PRD83(2011)091503, PRD81(2010)054028 (2010), PRD82(2010)054018, arXiv:1205.3453

single-top electroweak production

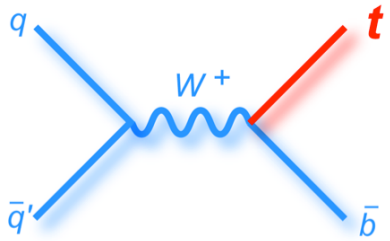
t channel



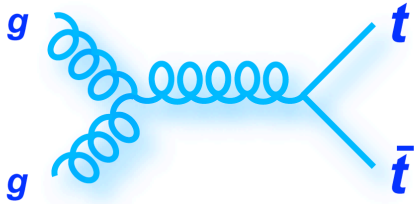
t W channel

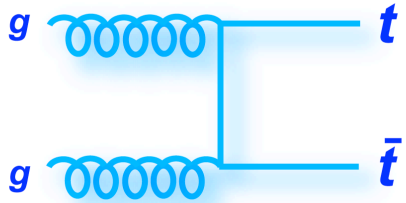


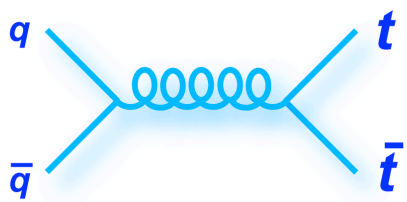
s channel



top-pair strong production

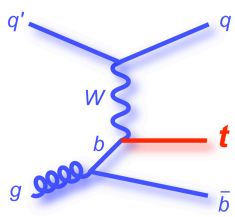






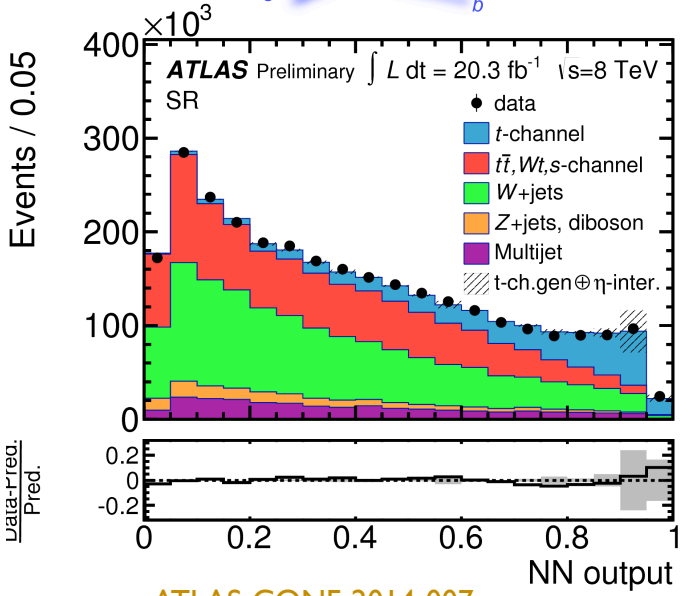
		t ch.	tW ch.	s ch.	$t\bar{t}$
Tevatron ($p\bar{p}$)	2 TeV	2.08pb	0.25pb	1.05pb	7.08pb
LHC (pp)	7 TeV	64.6pb	15.6pb	4.59pb	172pb
	8 TeV	87.6pb	22.2pb	5.55pb	249pb
	14 TeV	248pb (×3.2)	84.8pb (×3.8)	11.9pb (×2.1)	954pb (×3.9)

t channel: ATLAS



- ATLAS: new update with 20 fb^{-1} at 8 TeV, NN analysis using 14 discriminating variables
- Signal selection: one e or μ, 2jets-1tag events
- Multijet background rate determined from data (ME_T fit)
- Fiducial cross-section determined within detector acceptance:
  - $\sigma_{t\text{-ch.}}^{\text{fid.}}$ =3.37 ± 0.05 (stat) ± 0.47 (syst) ± 0.09(lumi) pb
- Largest systematics: jet energy scale, signal generator (ACERMC vs aMC@NLO)

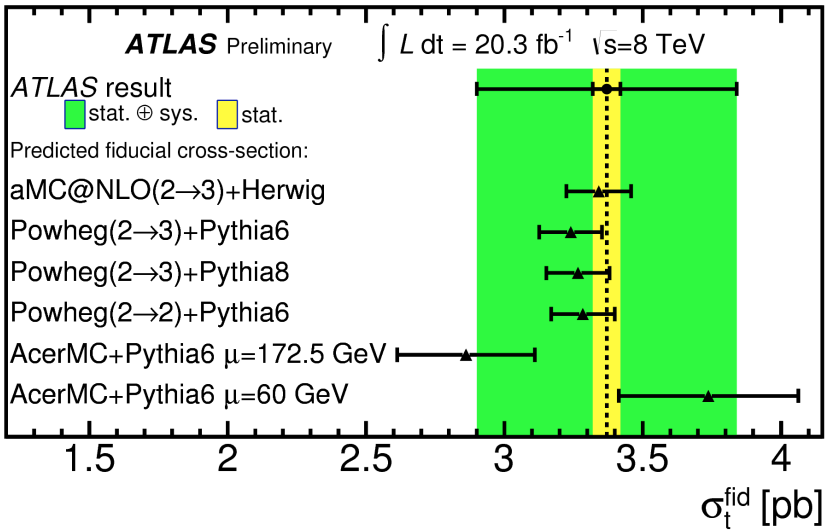
NEW



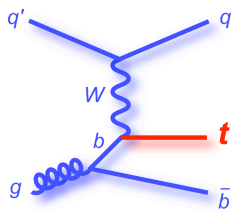
ATLAS-CONF-2014-007,
Presented for the 1st time in this conference

Fiducial volume:

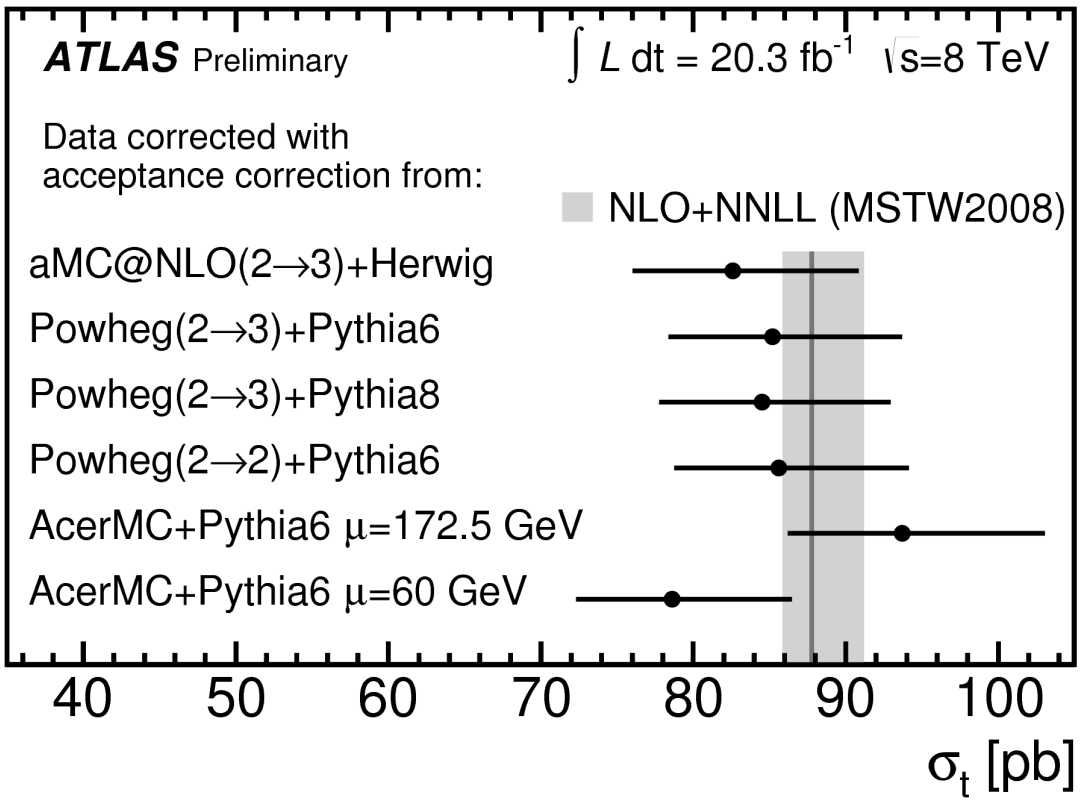
Object	Cut
Electrons	$p_T > 25$ GeV and $\|\eta\| < 2.5$
Muons	$p_T > 25$ GeV and $\|\eta\| < 2.5$
Jets	$p_T > 30$ GeV and $\|\eta\| < 4.5$
	$p_T > 35$ GeV, if $2.75 < \|\eta\| < 3.5$
Lepton (ℓ), Jets (j_i)	$\Delta R(\ell, j_i) > 0.4$
E_T^{miss}	$E_T^{miss} > 30$ GeV
Transverse W-boson mass	$m_T(W) >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



t channel: ATLAS

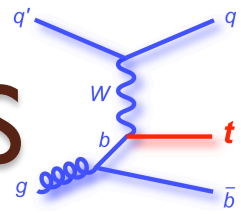


- Extrapolated to the entire phase space using various generator assumptions
- Assuming aMC@NLO + Herwig:
  - $\sigma_{t\text{-ch.}} = 82.6 \pm 1.2(\text{stat}) \pm 11.4(\text{syst}) \pm 3.1(\text{PDF}) \pm 2.3(\text{lumi})$ pb



NEW

t channel: CMS



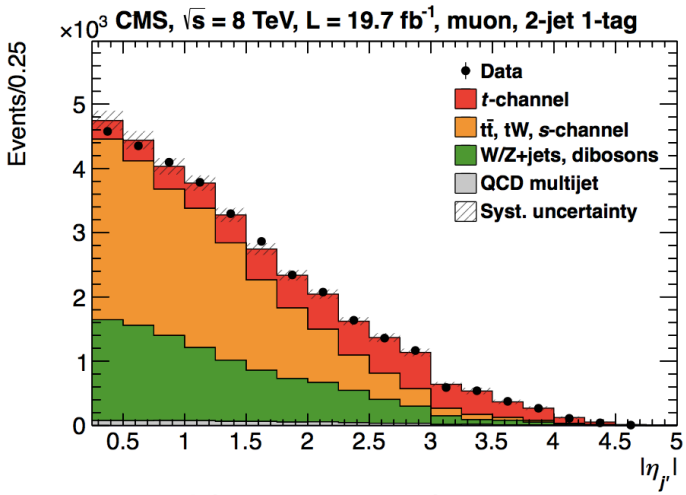
- CMS: updated 8 TeV analysis with the entire dataset
- Signal region: one e or μ, 2jets-1tag events, reconstr. top mass window: $130<m_{lvb}<220$ GeV
- Shapes for W+jets and $t\bar{t}$ are determined from control regions in data (m_{lvb} SB, 3jet-2tag)
- Signal, W+jets, $t\bar{t}$ yields determined from a fit to the $|\eta_{j'}|$ distribution
  - $\sigma_{t\text{-ch.}} = 83.6 \pm 2.3(\text{stat}) \pm 7.4(\text{syst})$ pb
  - $R_{8/7} = 1.24 \pm 0.08(\text{stat}) \pm 0.12(\text{syst})$

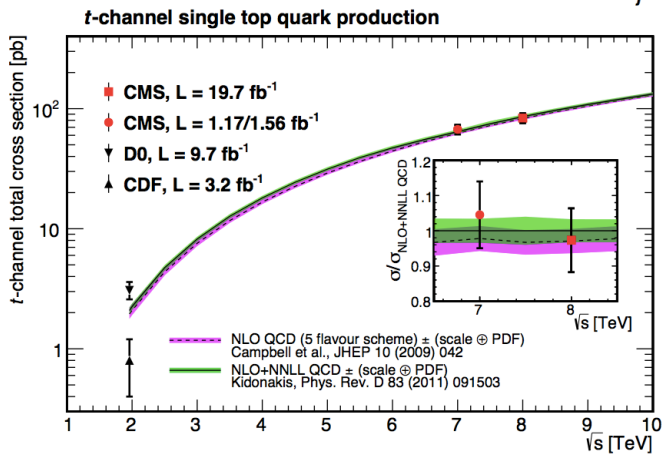
NEW

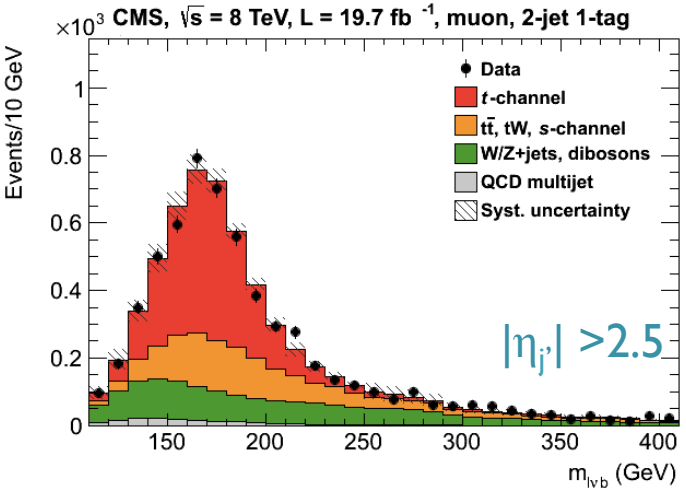
- Largest uncertainty: signal modeling (POWHEG vs COMPHEP), jet energy scale

- LHC Combination: (TOPLHCWG, using BLUE), using preliminary result (CMS PAS TOP-12-011, ATLAS-CONF-2012-132) :
  - $\sigma_{t\text{-ch.}} = 85 \pm 4(\text{stat}) \pm 11(\text{syst}) \pm 3(\text{lumi})$ pb
    $= 85 \pm 12$ pb
- To be updated with latest results!

~~CMS-PAS-TOP-12-011~~ → to be sub. to JHEP
LHC combination:
CMS PAS TOP-12-002/ATLAS-COM-CONF-2013-061

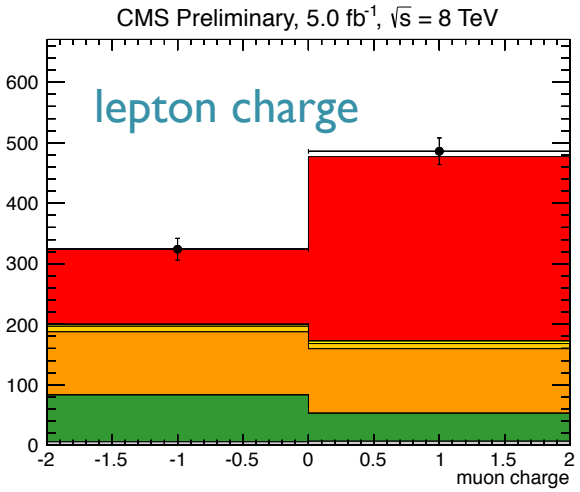


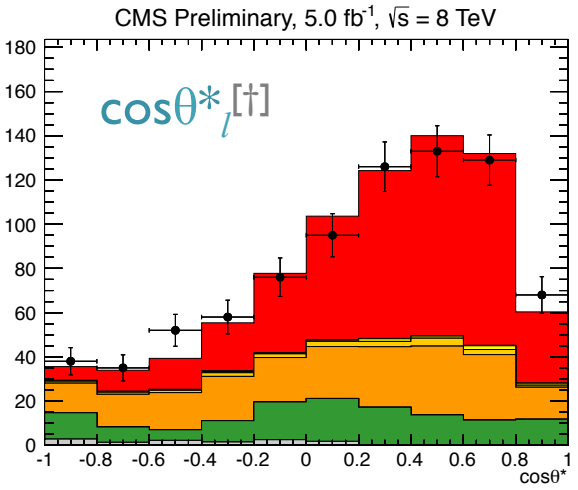




t channel: distributions

- The *t*-channel data sample is large enough to study distributions
  - → differential cross sections
- Signal can be enhanced by requiring e.g.: large forward jet pseudorapidity: $|\eta_{j'}| > 2.0$





Top/antitop cross-section ratio

Top polarization (W helicity, CMS PAS TOP-12-020)

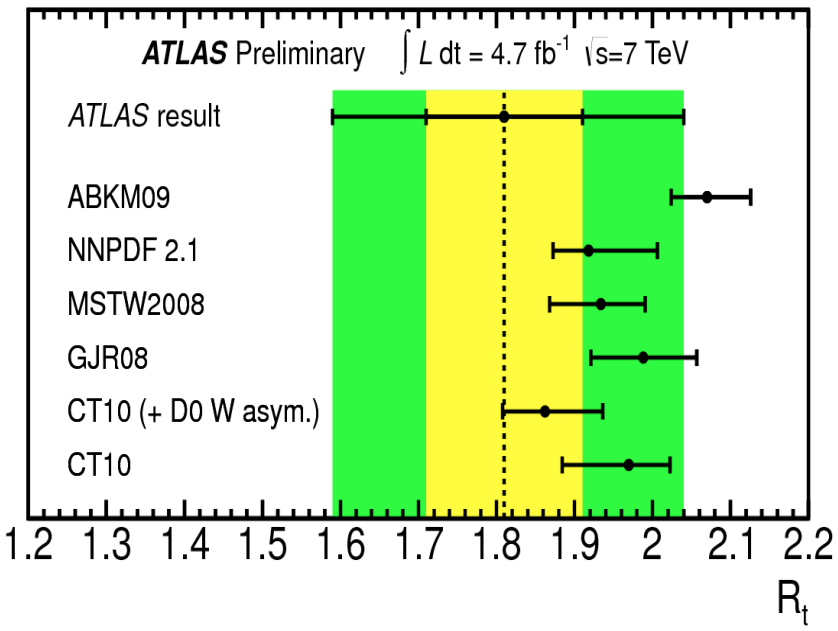
[†] θ^*_l = angle between lepton in W rest frame and the W in top rest frame.

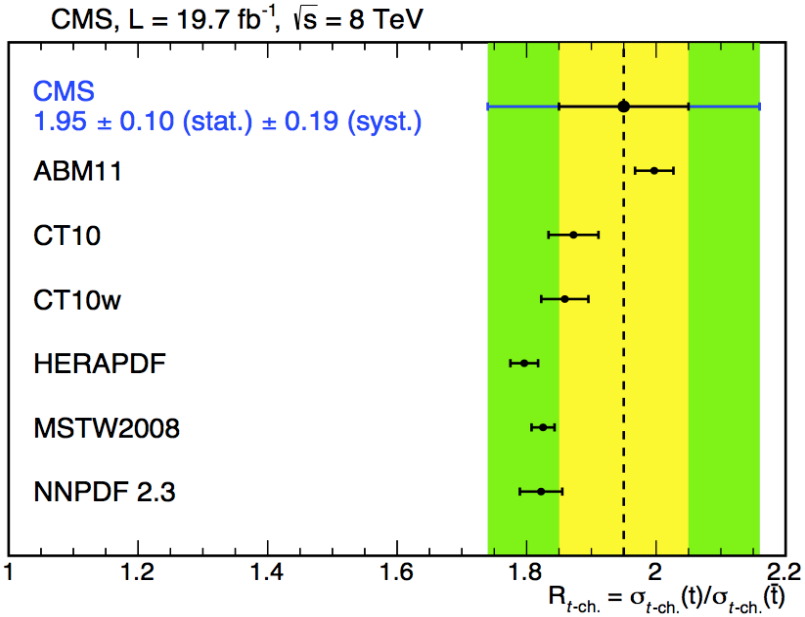
7 TeV: ATLAS-CONF-2012-056
8 TeV : ~~CMS PAS TOP-12-038~~
→ to be sub. to JHEP

Charge ratio

- 7 TeV (ATLAS):
  - $\sigma_t(t) = 53.2 \pm 10.8$ pb, $\sigma_t(\bar{t}) = 29.5\ ^{+7.4}_{-7.5}$ pb
  - $R_t = \sigma_t(t)/\sigma_t(\bar{t}) = 1.81^{+0.23}_{-0.22}$
  - Main systematics on R_t: background normalization (multijet from data, other from MC), JES
- 8 TeV (CMS):
  - $\sigma_t(t) = 53.8 \pm 1.5(\text{stat}) \pm 4.4(\text{syst})$ pb, $\sigma_t(\bar{t}) = 27.6 \pm 1.3(\text{stat}) \pm 3.7(\text{syst})$ pb
  - $R_t = \sigma_t(t)/\sigma_t(\bar{t}) = 1.95 \pm 0.10(\text{stat}) \pm 0.19(\text{syst})$
  - Main systematics on R_t: PDF uncert., signal modeling
- R_t potentially sensitive to PDF
- Approaching the precision necessary to discriminate between different PDF models

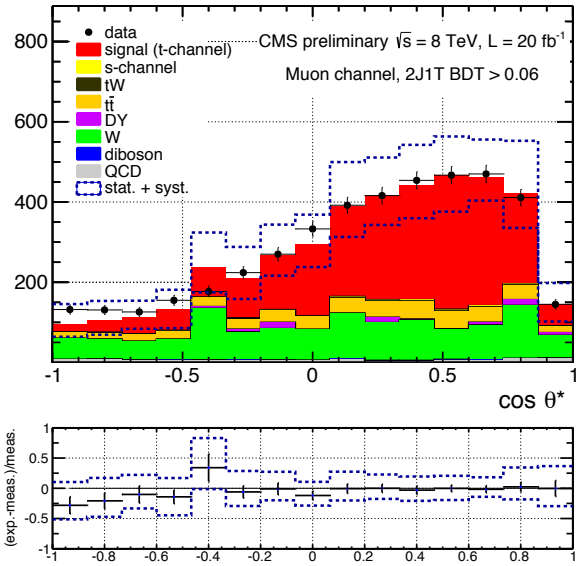
NEW

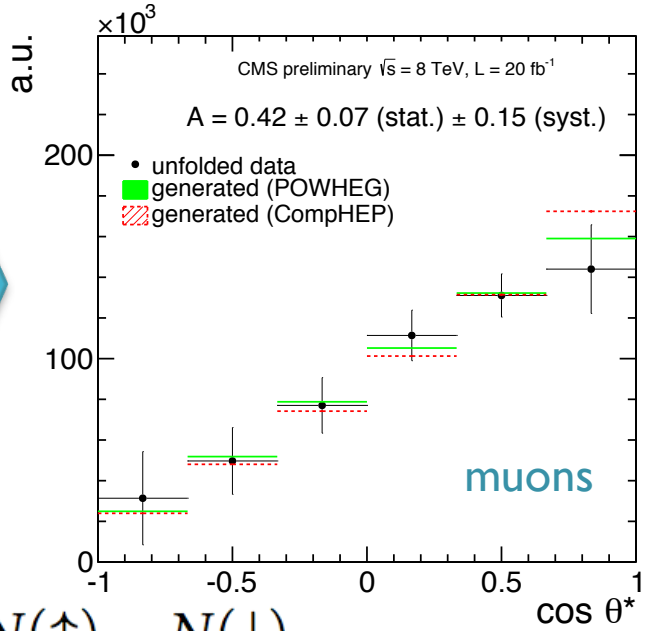




Top polarization

- Regularized unfolding of cosθ* distribution, after selection based on BDT discriminant, removes experimental effects
- First of several possible differential cross-section measurements





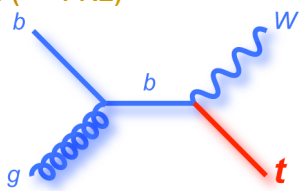
$$A_l \equiv \frac{1}{2} \cdot P_t \, \alpha_l = \frac{N(\uparrow) - N(\downarrow)}{N(\uparrow) + N(\downarrow)}$$

α_l =1 in the SM, modified in case of tWb anomalous coupling

- Top spin asymmetry: A_l = 0.41± 0.06(stat) ± 0.16(syst)
- Top polarization: P_l = 0.82 ± 0.12(stat) ± 0.32(syst)

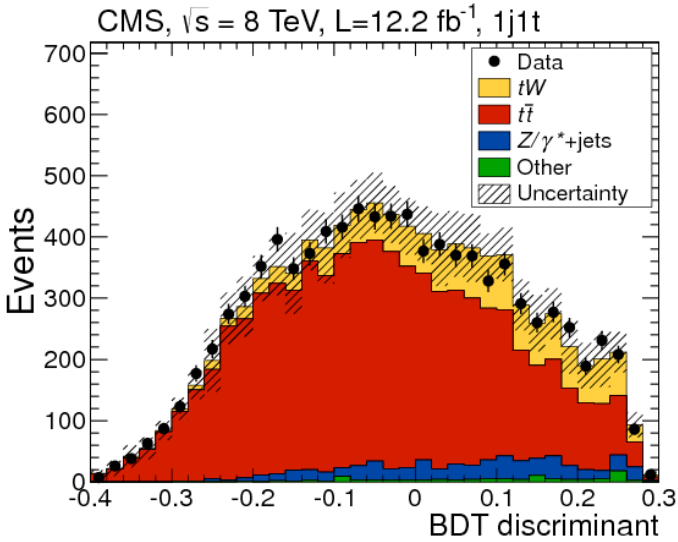
tW production

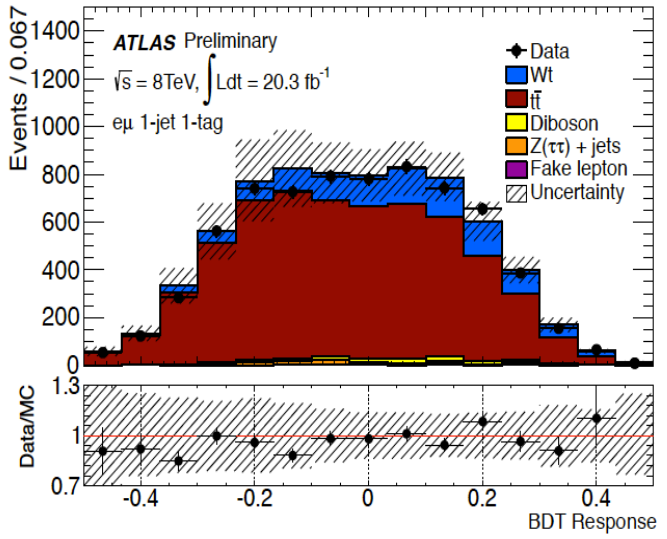
7 TeV: ATLAS Phys.Lett.B 716 (2012) 142-159,
CMS: Phys.Rev.Lett 110, 022003 (2013)
8 TeV: ATLAS-CONF-2013-100,
CMS: PAS-TOP-12-040 arxiv:1401.2942 (→ PRL)



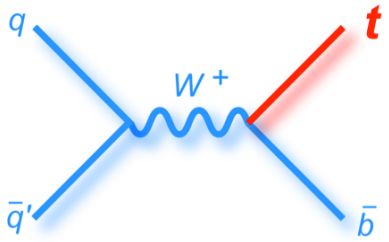
- Background limited analysis; BDT discriminant used by both experiments
- Evidence at 7 TeV reported by both ATLAS and CMS
- 8TeV:
  - CMS (12.2fb^{-1}):
    $\sigma_{tW} = 23.4^{+5.5}_{-5.4}$ pb
    6.1σ obs. ($5.4^{+1.5}_{-1.4}$σ exp.)
    Main systematics: ME/PS matching, ren./fact. scale, top-quark mass (could be replaced by x-sec. slope)
  - ATLAS (20.3fb^{-1}):
    $\sigma_{tW} = 27.2 \pm 2.8(stat) \pm 5.4(syst)$ pb
    4.2σ obs. (4.0σ exp.)
    Main systematics: b tagging, $t\bar{t}$ modeling, ISR/FSR

Observation





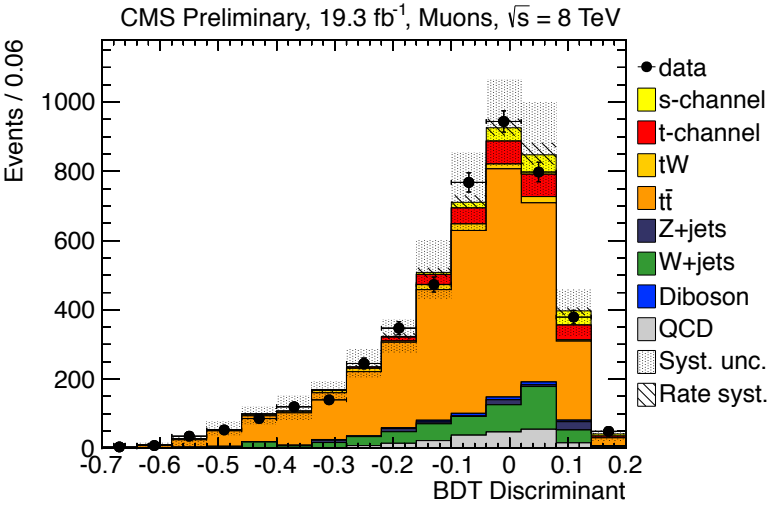
s channel

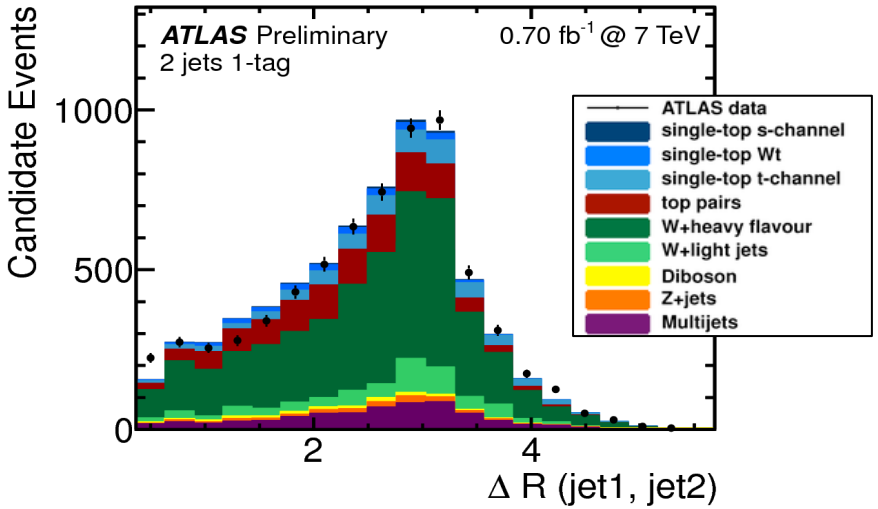


7 TeV: ATLAS-CONF-2011-118
8 TeV: CMS-PAS-TOP-13-009

NEW

- ATLAS: 7 TeV upper limit: $\sigma_{s\text{-ch.}} < 26.5$ pb $= 5.8\times\sigma^{SM}$, 95%CL
  - cut-based analysis, 2011 result using 0.7 fb^{-1}
- CMS: 8 TeV upper limit: $\sigma_{s\text{-ch.}} < 11.5$ pb $= 2.1\times\sigma^{SM}$, 95%CL
- Assuming SM signal: $\sigma_{s\text{-ch}} = 6.2^{+8.0}_{-5.1}$ pb (68% FC interval)
  - BDT analysis, sensitivity still limited (0.9σ exp, 0.7σ obs), mainly by theory systematics
- Keeping under control uncertainties like renorm./factor. scale could bring an important reduction to the uncertainty:
  - use NLO MC for $t\bar{t}$ background in future studies





$|V_{tb}|$ from single top

- The $|V_{tb}|$ measurement in single-top events provides a unique opportunity to directly probe the top production Wtb vertex: $|V_{tb}| = (\sigma/\sigma^{th}(|V_{tb}|=1))^{1/2}$, assuming $|V_{tb}| \gg |V_{ts}|, |V_{td}|$ or equivalently $B(t \to Wb) = 1$
  - Deviations from the SM are potentially sensitive to new physics
- Eight measurements in the *t* channel and in tW, the latter with less precision

- ATLAS:
  - 7 TeV: $|V_{tb}| = 1.13^{+0.14}_{-0.13}$ (t-ch., 11.9%)
    $|V_{tb}| = 1.03^{+0.16}_{-0.19}$ (tW, 17.0%)
  - 8 TeV: $|V_{tb}| = 0.97 \pm 0.01(stat)^{+0.06}_{-0.07}(syst) \pm 0.6(gen+PDF)^{+0.02}_{-0.01}(th) \pm 0.01(lumi)$ NEW
    $= 0.97^{+0.09}_{-0.10}$ (t-ch., 9.8%)
    $|V_{tb}| = 1.10 \pm 0.12(exp) \pm 0.03(th)$ (tW, 11.2%)
- CMS:
  - 7 TeV: $|V_{tb}| = 1.020 \pm 0.046(exp) \pm 0.017(th)$ (t-ch. 4.8%)
    $|V_{tb}| = 1.01^{+0.16}_{-0.13}(exp)^{+0.03}_{-0.04}(th)$ (tW, 14.8%)
  - 8 TeV: $|V_{tb}| = 0.979 \pm 0.045(exp) \pm 0.016(th)$ (t-ch. 4.9%)
    $|V_{tb}| = 1.03 \pm 0.12(exp) \pm 0.04(th)$ (tW 12.3%)

NEW

$|V_{tb}| = 0.998 \pm 0.038(exp) \pm 0.016(th)$
(7+8 TeV t-ch., comb.: 4.1%)

- Considering ATLAS+CMS combination with future updates

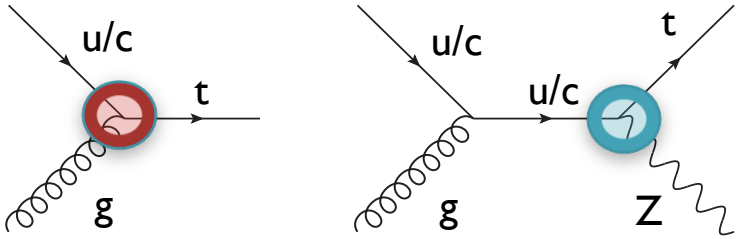
New physics in single top

- FCNC in single-top production may arise from several new physics scenarios affecting both production (u/c→t) and decay (e.g: u/c→tZ, tγ, tg)

$$\mathcal{L} = \sum_{q=u,c} \left[\sqrt{2} g_s \frac{\kappa_{gqt}}{\Lambda} \bar{t} \sigma^{\mu\nu} T_a (f_q^L P_L + f_q^R P_R) q \, G^a_{\mu\nu} + \frac{g}{\sqrt{2} c_W} \frac{\kappa_{Zqt}}{\Lambda} \bar{t} \sigma^{\mu\nu} (\hat{f}_q^L P_L + \hat{f}_q^R P_R) q \, Z_{\mu\nu} \right] + \text{h.c.}$$

gut, gct

Zut, Zct



ATLAS:

$\kappa_{gut}/\Lambda < 5.1 \times 10^{-3}$ TeV^{-1}

$\kappa_{gct}/\Lambda < 1.1 \times 10^{-2}$ TeV^{-1}

CMS:

$\kappa_{Zut}/\Lambda < 0.45$ TeV^{-1}

$\kappa_{Zct}/\Lambda < 2.27$ TeV^{-1}

$B(t \to gu) < 3.1 \times 10^{-5}$

$B(t \to gc) < 1.6 \times 10^{-5}$

$B(t \to Zu) < 5\text{-}1 \times 10^{-3}$

$B(t \to Zc) < 0.1140$

(95% CL)

- ATLAS searches for FCNC in single top production with SM t→Wb decay (ATLAS-CONF-2013-063, 8 TeV)
- CMS looked for FCNC in associated tZ production (CMS PAS TOP-12-021, 7 TeV)
- ATLAS also looked for CP violation in the Wtb vertex using lepton angular distribution in single-top (ATLAS-CONF-2013-032, 7 TeV)
- No deviation from SM prediction spotted so far

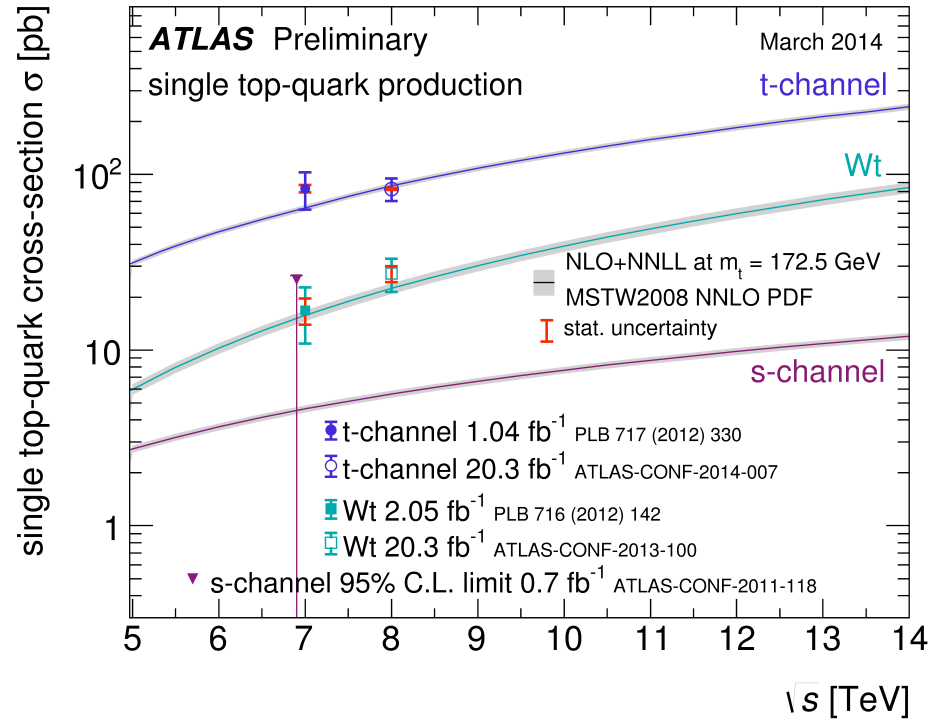
$A_{FB}^N = 0.031 \pm 0.065(\text{stat.})^{+0.029}_{-0.031}(\text{syst})$

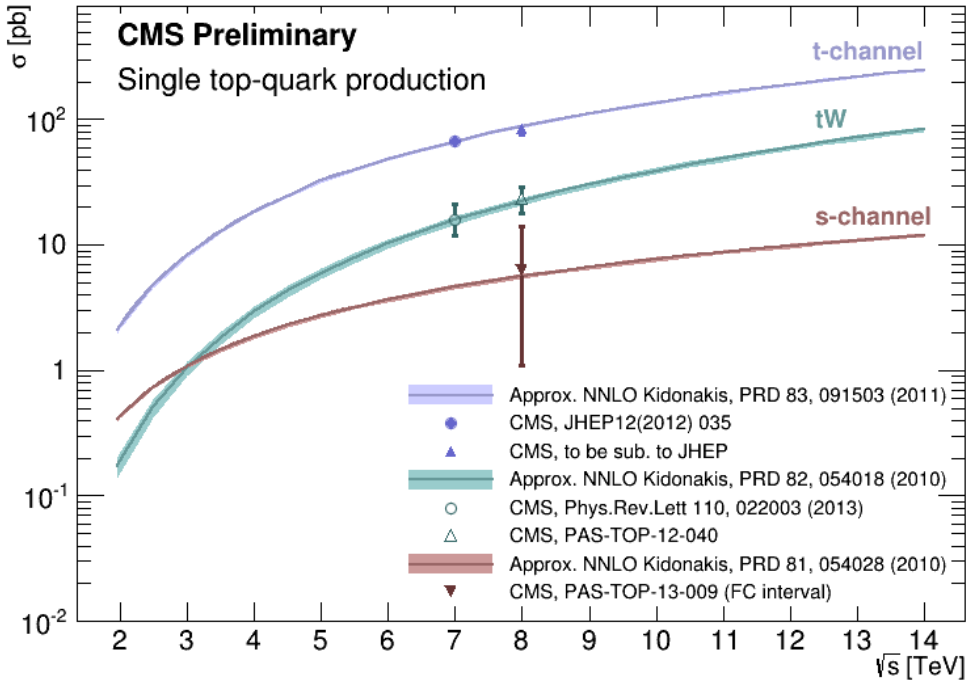
anomalous tensor coupling:

$-0.2 < \Im(g_R) < 0.3$, 95%CL

Single top cross sect. summary

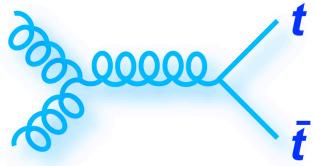
- All measurements are in agreement with approx. NNLO calculations





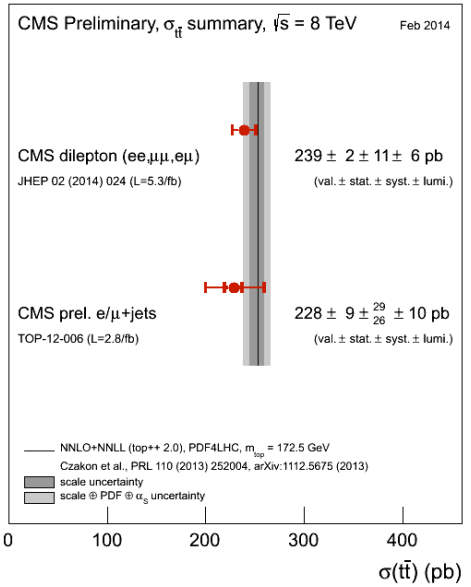
CMS: JHEP 02(2014)024

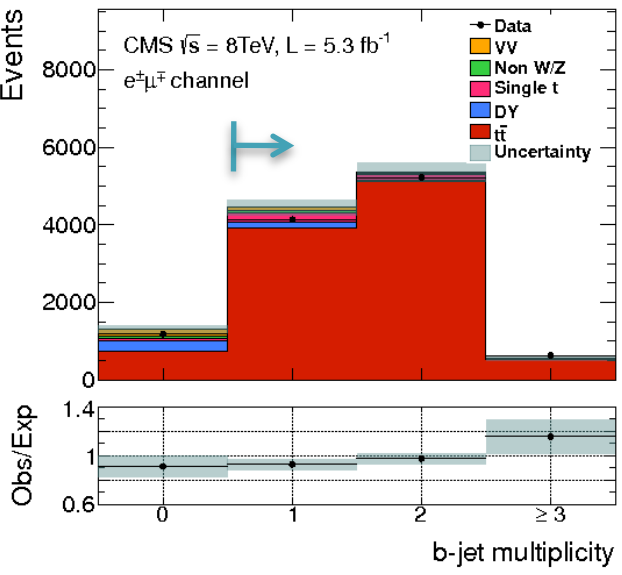
NEW

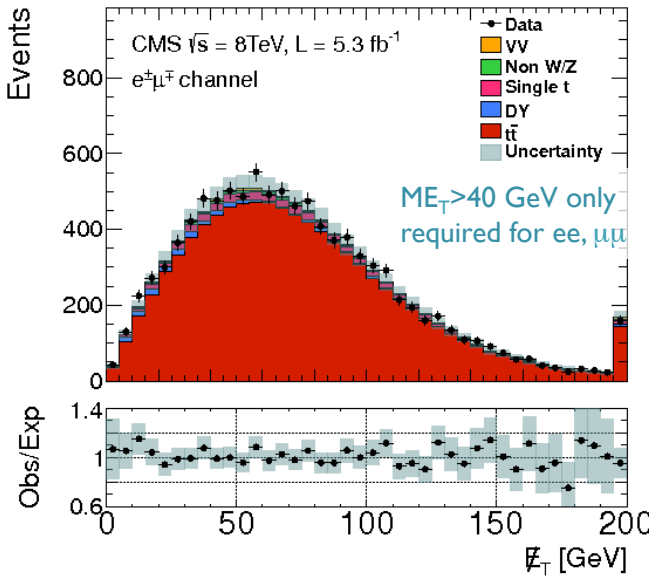


$t\bar{t}$ inclusive: CMS, dileptons

- Recent CMS measurement at 8 TeV using 5.3 fb^{-1} in e and μ channels using b tag
- Dominated, by eμ, significantly less affected by DY background (determined from Z mass SB in data)
- Largest systematics: fact./ren. scale, lepton efficiency, jet energy scale
  - $\sigma_{t\bar{t}} = 239 \pm 2\ (stat) \pm 11\ (syst) \pm 6\ (lum)$ pb **(5.3%)**







Source	e^+e^-	$\mu^+\mu^-$	$e^\pm\mu^\mp$
Trigger efficiencies	4.1	3.0	3.6
Lepton efficiencies	5.8	5.6	4.0
Lepton energy scale	0.6	0.3	0.2
Jet energy scale	10.3	10.8	5.2
Jet energy resolution	3.2	4.0	3.0
b-jet tagging	1.9	1.9	1.7
Pileup	1.7	1.5	2.0
Scale (μ_F and μ_R)	5.7	5.5	5.6
Matching partons to showers	3.9	3.8	3.8
Single top quark	2.6	2.4	2.3
VV	0.7	0.7	0.5
Drell–Yan	10.8	10.3	1.5
Non-W/Z leptons	0.9	3.2	1.9
Total systematic	18.6	18.6	11.4
Integrated luminosity	6.4	6.1	6.2
Statistical	5.2	4.5	2.6

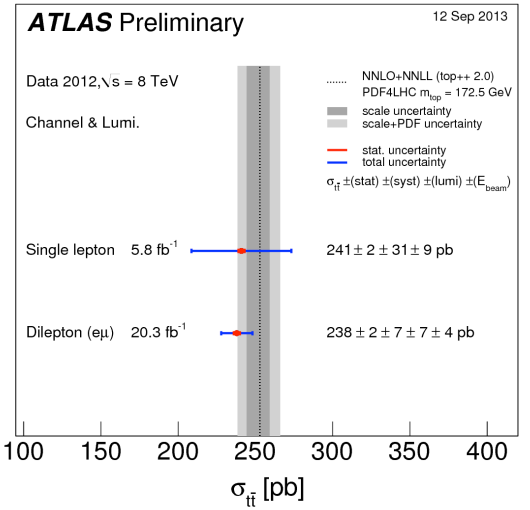
MET cut for SF leptons reflects in larger JES systematics

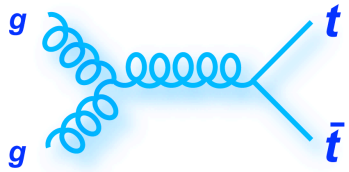
ATLAS-CONF-2013-097

$t\bar{t}$ inclusive: ATLAS, eμ

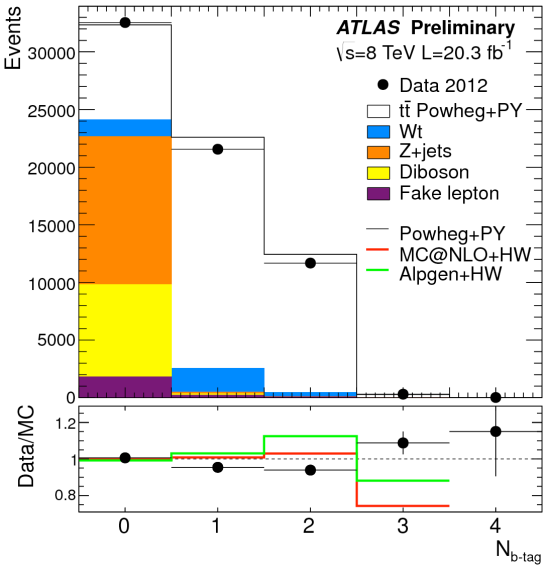
- One b-jet requirement, in-situ determination of b tagging efficiency from b-tag multiplicity distribution
- Largest systematics: electron ID, tt modeling, ISR/FSR, PDF
- σ_{tt^-} = 237.7 ± 1.7 (stat) ± 7.4 (syst) ± 7.4 (lumi) ± 4.0 (beam energy) pb

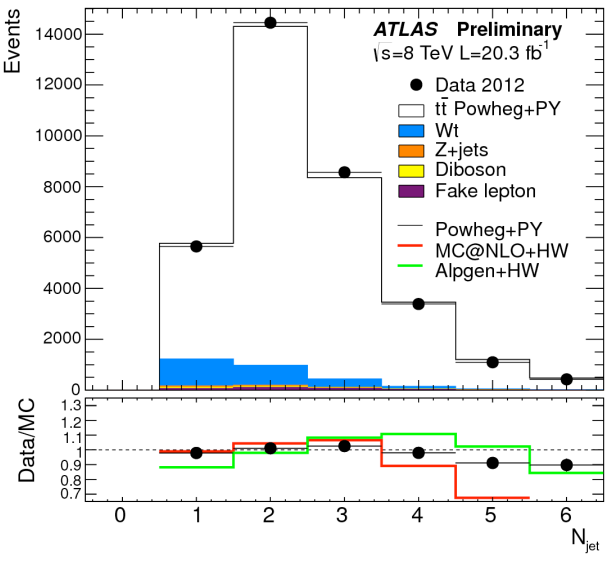
(4.8%)





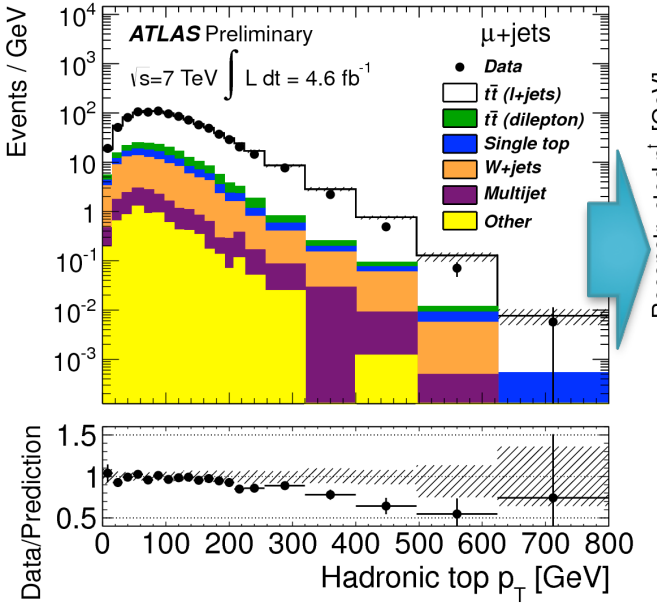
Uncertainty	$\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%)	$\Delta\sigma_{t\bar{t}}$ (pb)
Data statistics	0.72	1.7
$t\bar{t}$ modelling	1.52	3.6
Initial/final state radiation	1.23	2.9
Parton density functions	1.09	2.6
QCD scale choices	0.30	0.7
Single-top modelling	0.38	0.9
Single-top/$t\bar{t}$ interference	0.15	0.4
Single-top Wt cross-section	0.70	1.7
Diboson modelling	0.42	1.0
Diboson cross-sections	0.03	0.1
Z+jets extrapolation	0.05	0.1
Electron energy scale/resolution	0.48	1.1
Electron identification/isolation	1.42	3.4
Muon momentum scale/resolution	0.05	0.1
Muon identification/isolation	0.52	1.2
Lepton trigger	0.16	0.4
Jet energy scale	0.49	1.2
Jet energy resolution	0.59	1.4
Jet reconstruction/vertex fraction	0.04	0.1
b-tagging	0.42	1.0
Pileup modelling	0.28	0.7
Misidentified leptons	0.38	0.9
Total systematic	3.12	7.4
Integrated luminosity	3.11	7.4
LHC beam energy	1.70	4.0
Total uncertainty	4.77	11.3

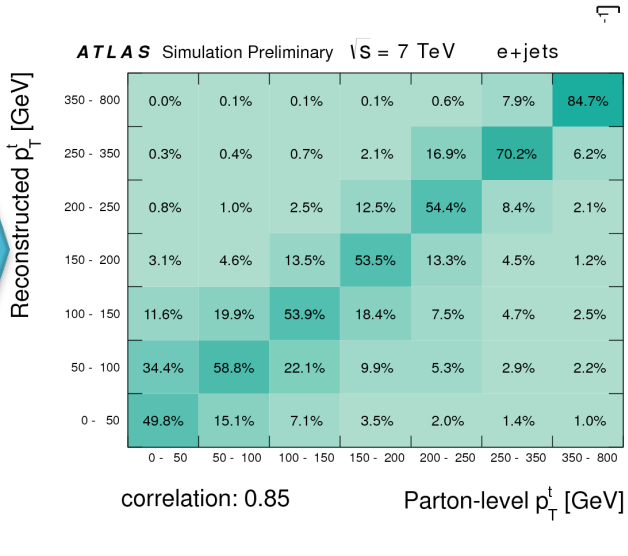


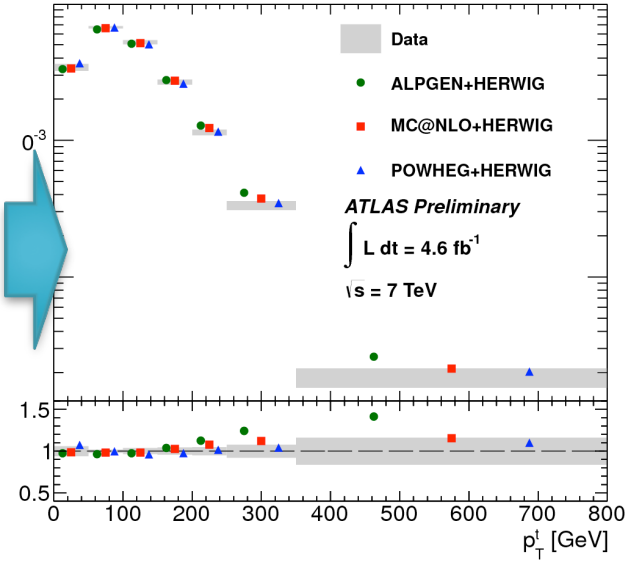


Differential measurements

- Precise measurements of top-quark distributions are a crucial task:
  - Tests of perturbative QCD in different phase space regions
  - Enhance sensitivity to New Physics in top processes
  - Control background for Higgs, rare processes and many BSM searches
- Unfold experimental distribution by instrumental effects correcting bin-by-bin migrations



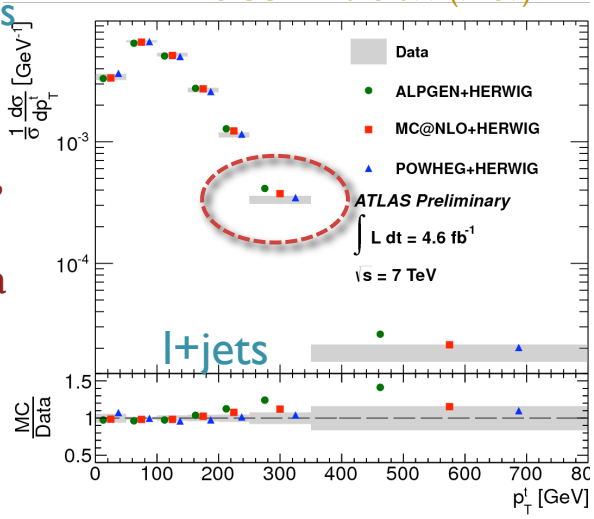




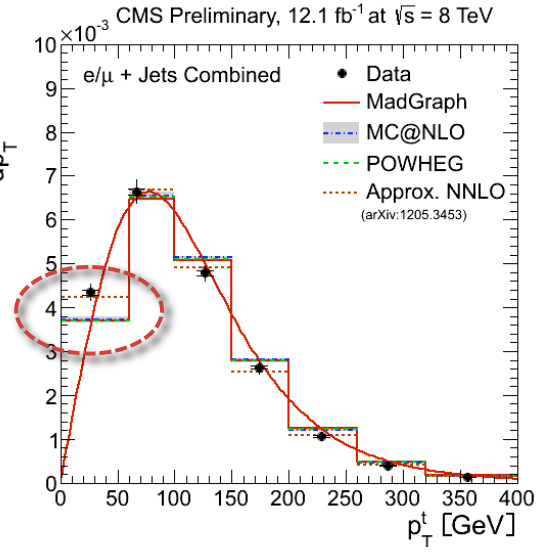
Top quark p_T, jet multiplicity

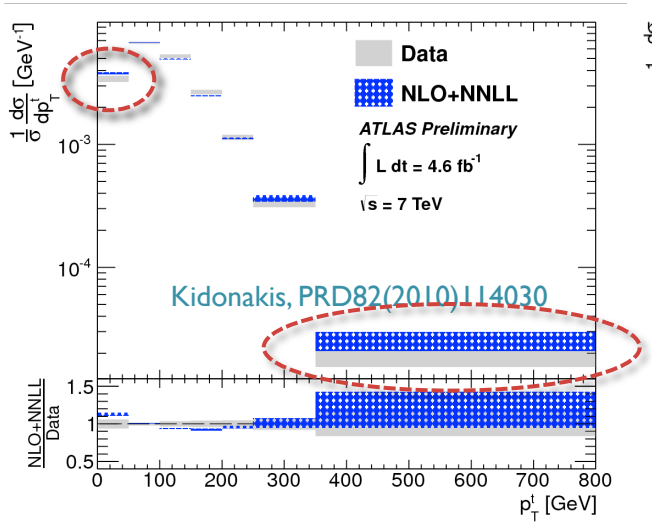
- Top p_T:
  - POWHEG best agrees with data
  - ATLAS reports ALPGEN, MC@NLO, and the NLO calculation above data for p_T > 200 GeV
  - CMS reports low pT spectrum not well reproduced, but in agreement with approx. NLO calculations
- Jet multiplicity:
  - MC@NLO+Herwig showering predicts lower jet multiplicity than observed

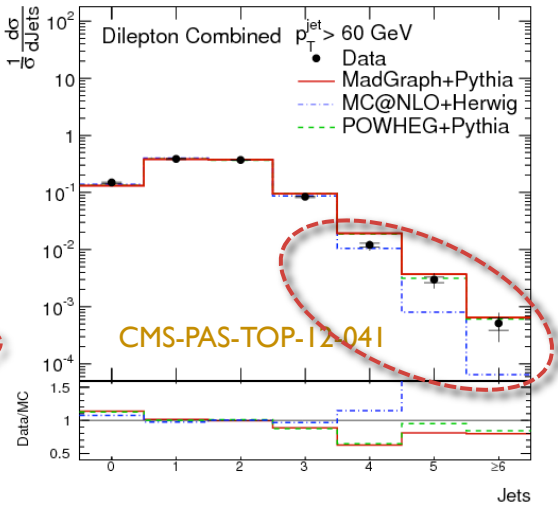
ATLAS-CONF-2013-099 (7 TeV)



CMS: EPJC73(2013)2339 (7 TeV)
CMS-PAS TOP-12-027 (l+jets, 8 TeV)
CMS-PAS TOP-12-028 (dileptons, 8 TeV)





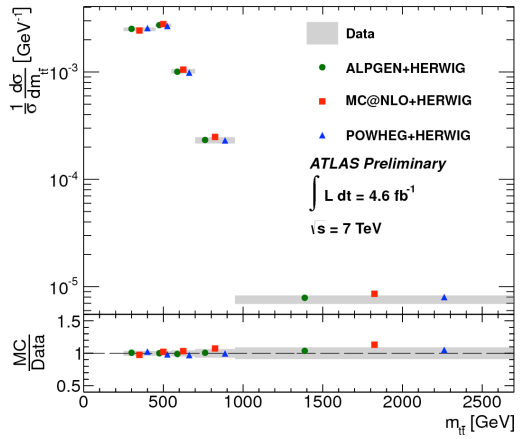


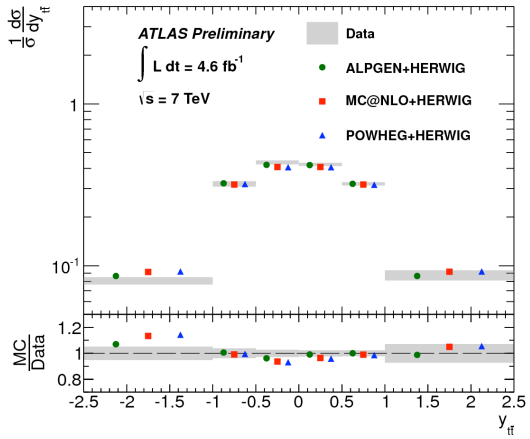
$t\bar{t}$ pair: m_{tt}, y_{tt}, p_T^{tt}

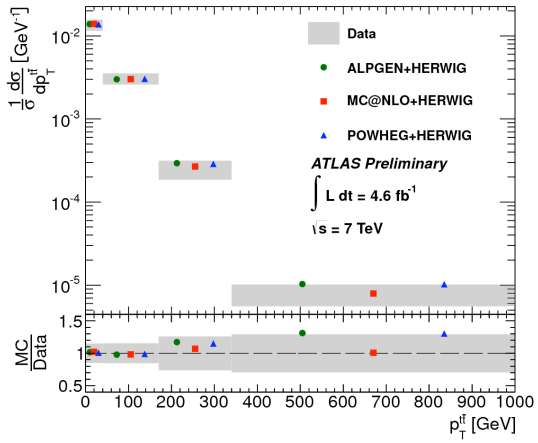
- Good agreement with theory predictions

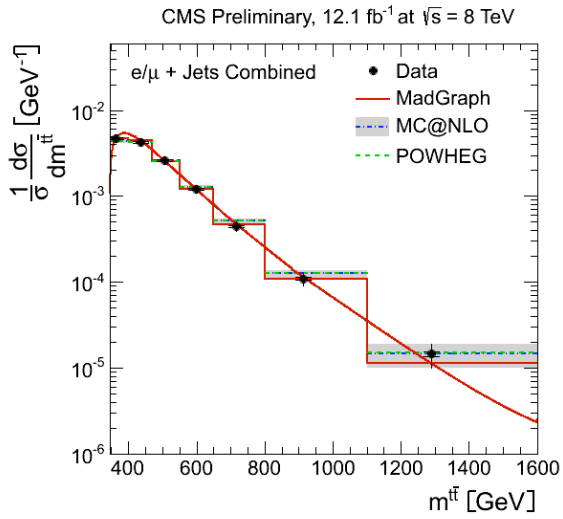
ATLAS-CONF-2013-099 (l+jets, 7 TeV)
ATLAS: EPJC73 (2013) 2339 (dileptons, 7 TeV)

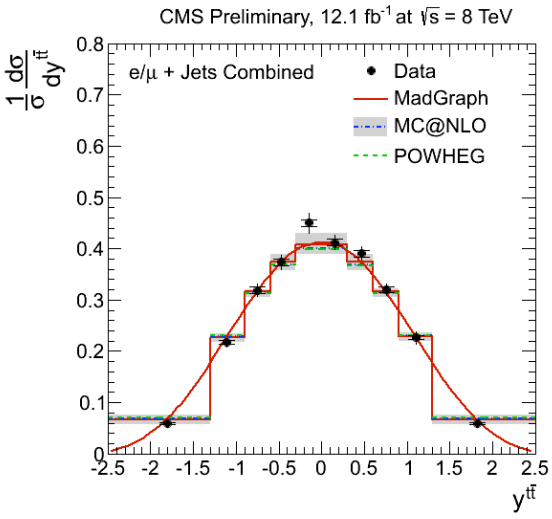
CMS-PAS TOP-12-027 (l+jets, 8 TeV)
CMS-PAS TOP-12-028 (dileptons, 8 TeV)

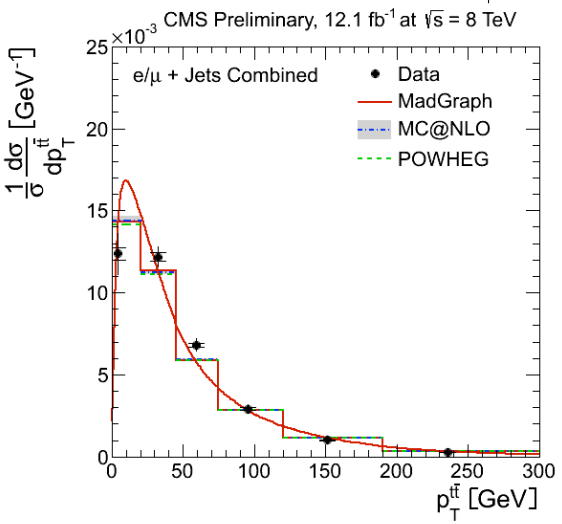






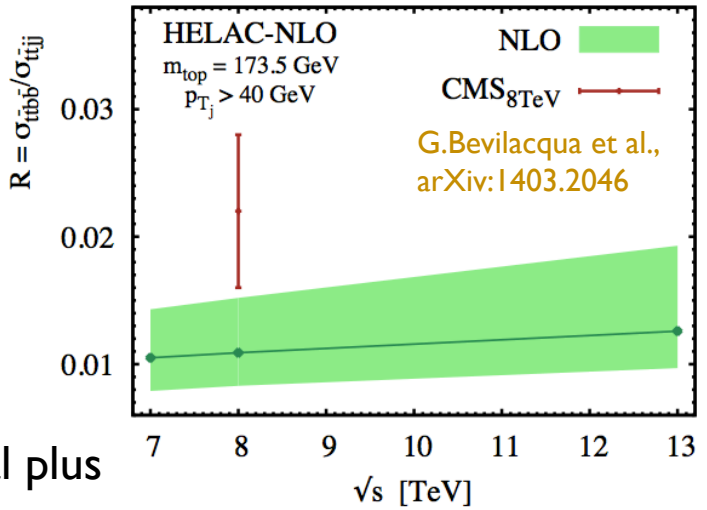






$t\bar{t}+b\bar{b}$, heavy flav.

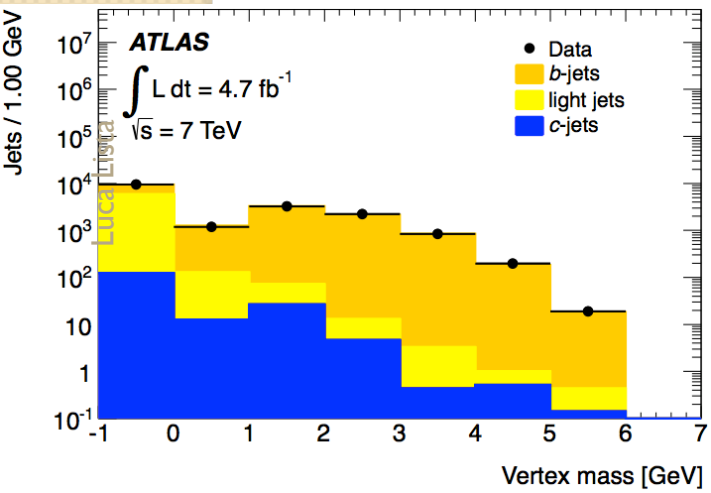
- Background to ttH and other searches
- $\sigma(t\bar{t}b\bar{b})/\sigma(t\bar{t}jj)$ measured by CMS in the dilepton mode (8 TeV)
- Fit to b-tag discriminator performed on signal plus background categories



$\sigma(t\bar{t}b\bar{b})/\sigma(t\bar{t}jj)$ =
0.023±0.003(stat)±0.005(syst), p_T(jet) > 20GeV
MADGRAPH/POWHEG: 0.016/0.017 ± 0.002
0.022±0.004(stat)±0.005(syst), p_T(jet) > 40GeV
MADGRAPH/POWHEG: 0.013/0.014 ± 0.002

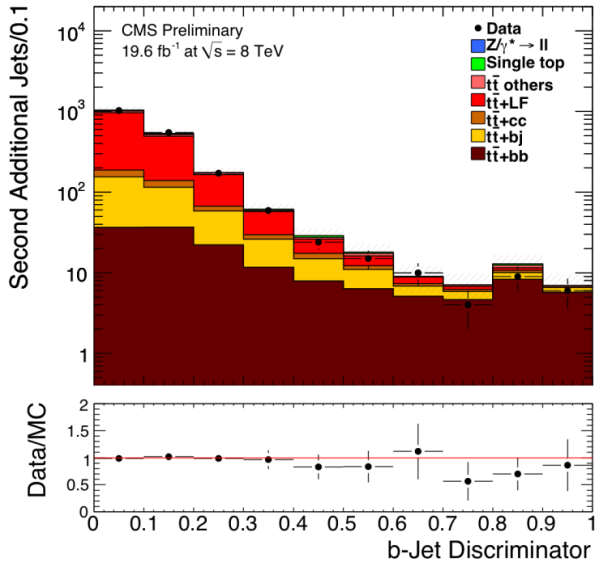
CMS-PAS-TOP-13-010, 8 TeV; CMS-PAS-TOP-12-024, 7 TeV

- ATLAS measured at 7 TeV the production cross section of $t\bar{t}+b+X$ or $t\bar{t}+c+X$:



$\sigma(t\bar{t}+b/c+X)/\sigma(t\bar{t}+\geq 1\text{jet})$,
p_T>25GeV, |η|<2.5 =
6.2±1.1(stat.)±1.8(syst.)%
ALPGEN: 3.4%

arXiv:1304.6386→PRD



$t\bar{t}$ +W, Z, γ

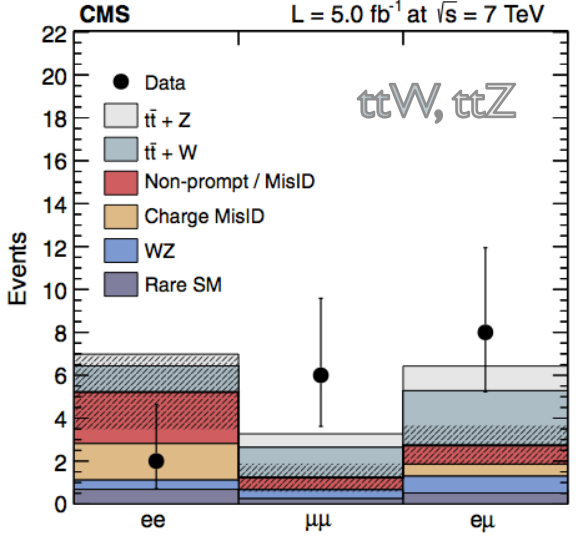
CMS PRL110.172002: ttV, 7 TeV
ATLAS-CONF-2011-153: ttγ, 7 TeV
CMS PAS TOP-13-011: ttγ, 8 TeV

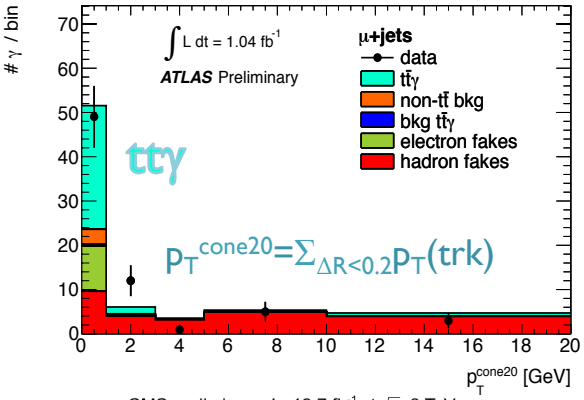
ttZ/W: CMS: Inclusive search for same-sign dilepton from ttV, V=W, Z, exclusive trilepton search from ttZ:

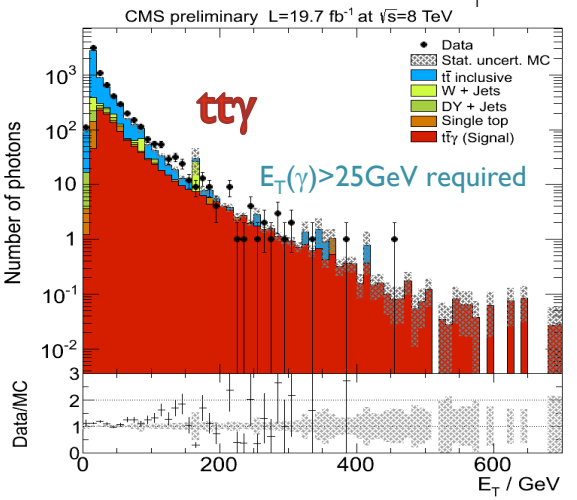
- $\sigma(ttV) = 0.43^{+0.17}_{-0.15}(stat)^{+0.09}_{-0.07}(syst)$ pb (3.0σ)
  SM: $0.306^{+0.031}_{-0.053}$pb (Garzelli et al.; JHEP11(2012)056)
- $\sigma(ttZ) = 0.28^{+0.14}_{-0.11}(stat)^{+0.06}_{-0.03}(syst)$ pb (3.3σ)
  SM: $0.137^{+0.012}_{-0.016}$pb (Campbell, Ellis: JHEP07(2012)052)

ttγ: l+jets used to detect tt pair; photon fake rate estimated from template fit of photon/ch. hadron isolation

- ATLAS, 7 TeV:
  $\sigma(tt\gamma) = 2.0 \pm 0.5(stat) \pm 0.7(syst) \pm 0.1(lumi)$ pb
  SM: 2.1±0.4pb, $E_T(\gamma)$>8GeV
  (W. Kilian et al.:EPJC71(2011)1742)
- CMS, 8 TeV:
  NEW
  $\sigma(tt\gamma)/\sigma(tt) = (1.07 \pm 0.07(stat) \pm 0.27(syst)) \times 10^{-2}$
  → $\sigma(tt\gamma) = 2.4 \pm 0.2(stat) \pm 0.6(syst)$pb
  SM: 1.8±0.5pb, $E_T(\gamma) > 20$GeV, $\Delta R(\gamma,b)>0.1$
  (K. Melnikov, et al., PRD83(2011)074013)
- Results compatible within uncertainties with NLO calculations



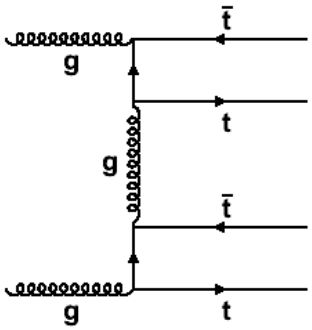




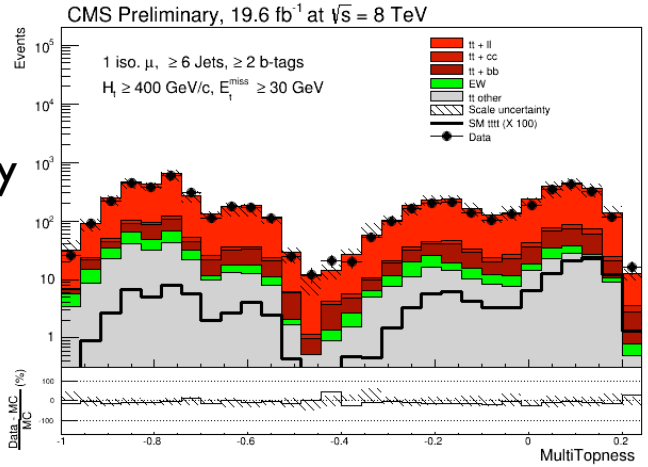
CMS-PAS-TOP-13-012
8 TeV, 20 fb^{-1}

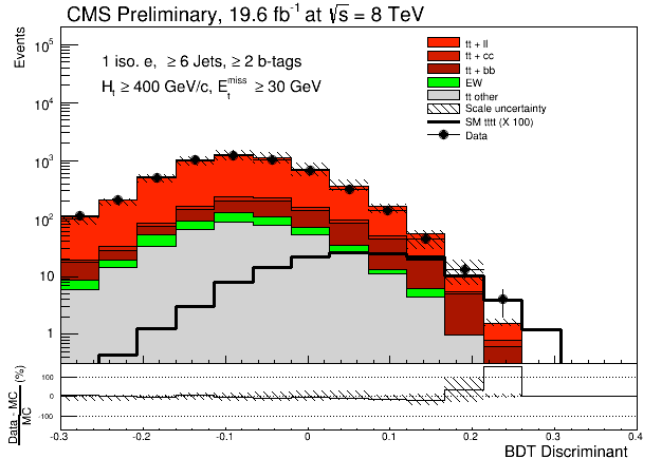
Search for four tops

NEW



- SM process with very low cross section:
  - $\sigma^{SM}_{8TeV}(tttt) \approx 1$ fb(LO) + ~20÷30% (NLO)
    V. Barger et al., PLB687(2010)70
    M.W. G. Bevilacqua, JHEP1207(2012)111
- Production largely enhanced in several models beyond the SM
  - Composite top and Higgs, extra dimensions, supersymmetric cascade decay with multitop final states, …)
- Analysis strategy look for:
  - ① top decay to e or μ
  - ③ tops decay hadronically
    - 3-jet combinations scored as top decay using a dedicated BDT ("multitopness") against semileptonic $t\bar{t}$
    - Second BDT adding more event variables
- No significant excess observed:
- $\sigma(tttt) < 63$ fb (exp: 42^{+18}_{-13} fb) , 95%CL





Conclusions

- Precision of top production measurements is steadily improving
- Focus now on precise understanding of top production mechanism
  - Detailed comparisons with state-of-the-art QCD predictions (NNLO, approx. NNLO and NLO +PS multi-leg MC)
  - Possibly find deviations from the Standard Model
- Cross section in fiducial regions, avoiding model-dependent extrapolations
- Next rounds:
  - Targeting ultimate precision for upcoming 7 and 8 TeV run-I legacy measurements
  - Get ready to look at run-II data at higher energy

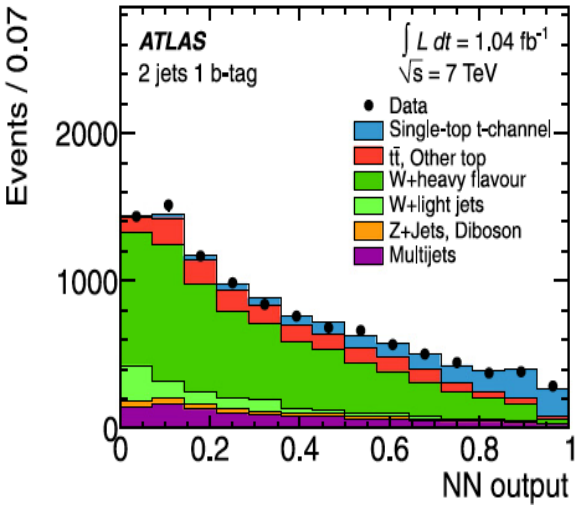
Thank you

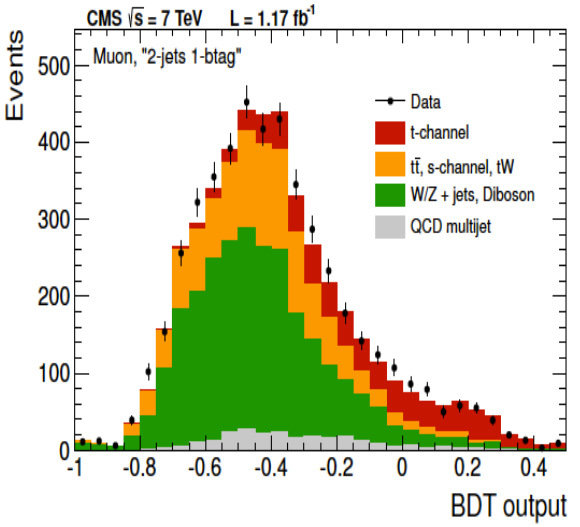
Backup

t channel: 7 TeV

ATLAS: PLB717(2012)330
CMS: JHEP12(2012)035

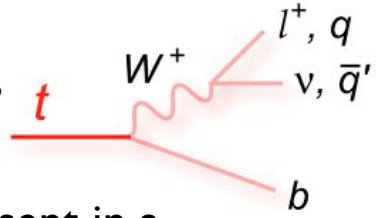
- ATLAS: NN Analysis, cut-based as cross check
- $\sigma_{t\text{-ch.}} = 83 \pm 4(\text{stat})^{+20}_{-19}(\text{syst})$ pb = 83±20 pb
- Cut-based: $\sigma_{t\text{-ch.}} = 92^{+29}_{-26}$ pb
- CMS: three analyses combined: NN, BDT and fit to $|\eta_{j'}|$
- $|\eta_{j'}|$: $\sigma_{t\text{-ch.}} = 70.0 \pm 6.0(\text{stat}) \pm 6.5(\text{syst}) \pm 3.6(\text{th}) \pm 1.5(\text{lumi})$ pb
- NN: $\sigma_{t\text{-ch.}} = 68.1 \pm 4.1(\text{stat}) \pm 3.4(\text{syst})^{+3.3}_{-4.3}(\text{th}) \pm 1.5(\text{lumi})$ pb
- BDT: $\sigma_{t\text{-ch.}} = 66.6 \pm 4.0(\text{stat}) \pm 3.3(\text{syst})^{+3.9}_{-3.3}(\text{th}) \pm 1.5(\text{lumi})$ pb
- Combination of the three:
- $\sigma_{t\text{-ch.}} = 67.2 \pm 3.7(\text{stat}) \pm 3.0(\text{syst}) \pm 3.5(\text{th}) \pm 1.5(\text{lumi})$ pb = 67.2±6.1 pb



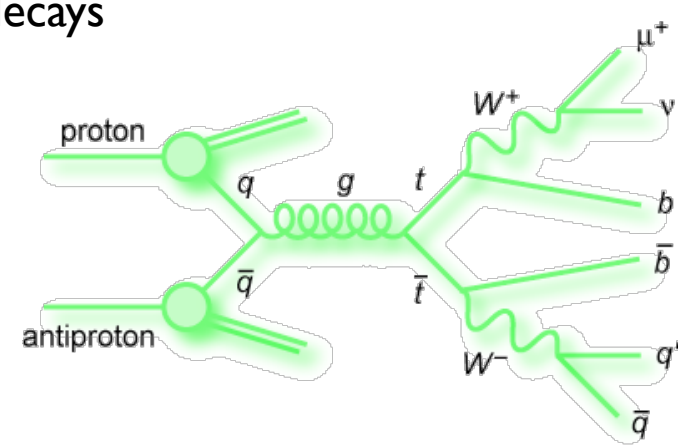


Final states in top pair events

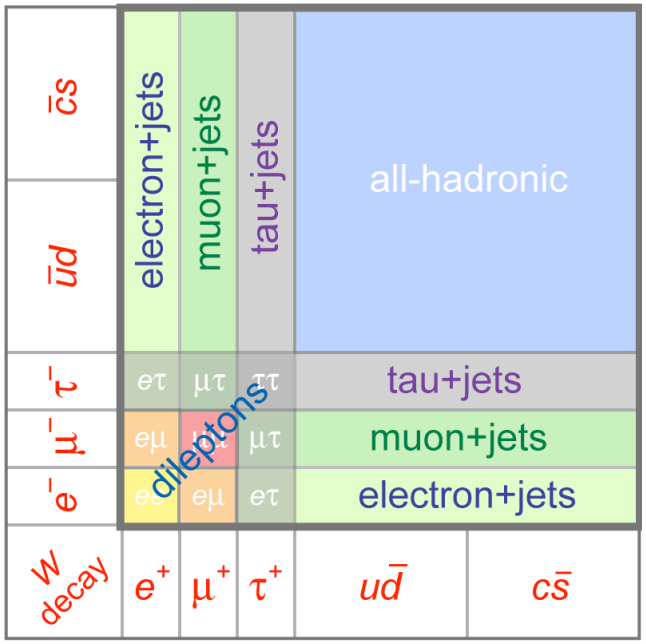
- W decays from t→Wb dictate top event signature
- Possible final states of $t\bar{t}^{bar}$ events:
  - Dileptons (e, μ): ~5%
  - Leptons + jets (e, μ): ~30%
  - All hadronic: ~45%
- At least two b-jets are present in a $t\bar{t}^{bar}$ event
- Neutrinos from leptonic W decays generate missing E_T (MET)
- Non-b jets are present in W hadronic decays



W^+ DECAY MODES	Fraction (Γ_i/Γ)
$\ell^+\nu$	(10.80± 0.09) %
$e^+\nu$	(10.75± 0.13) %
$\mu^+\nu$	(10.57± 0.15) %
$\tau^+\nu$	(11.25± 0.20) %
hadrons	(67.60± 0.27) %

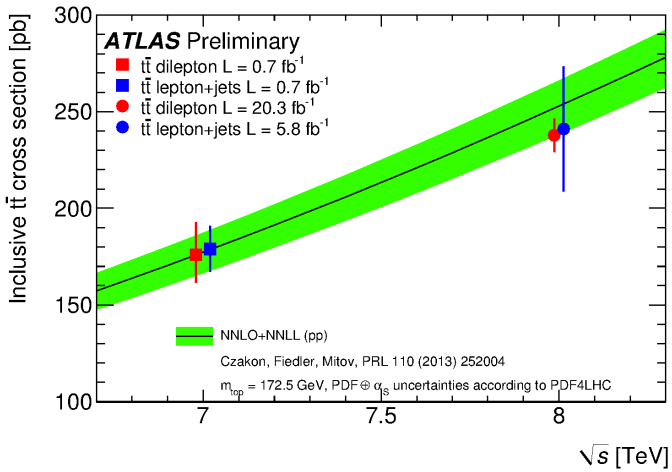


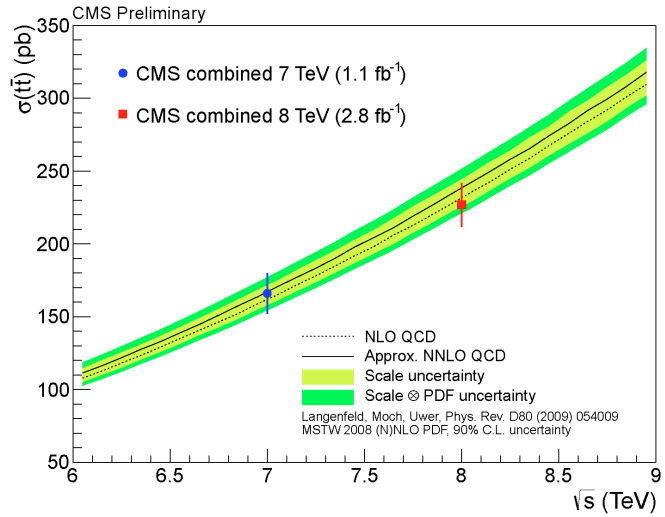
Top Pair Decay Channels

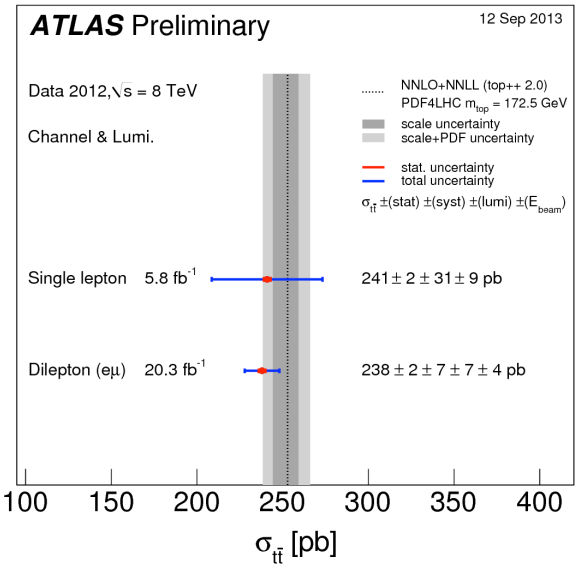


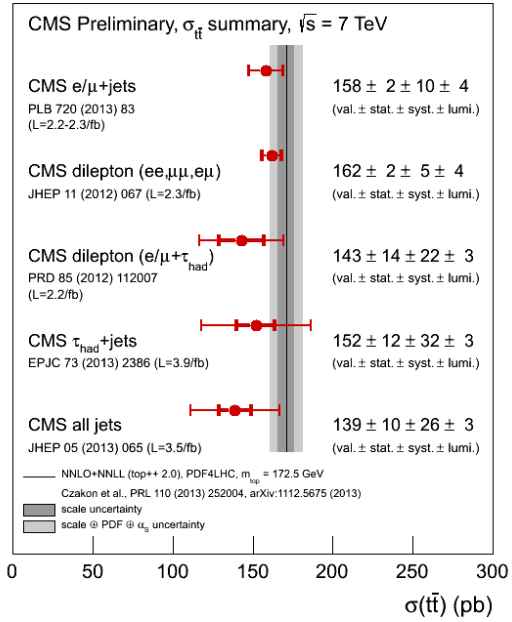
Inclusive $t\bar{t}$: summary

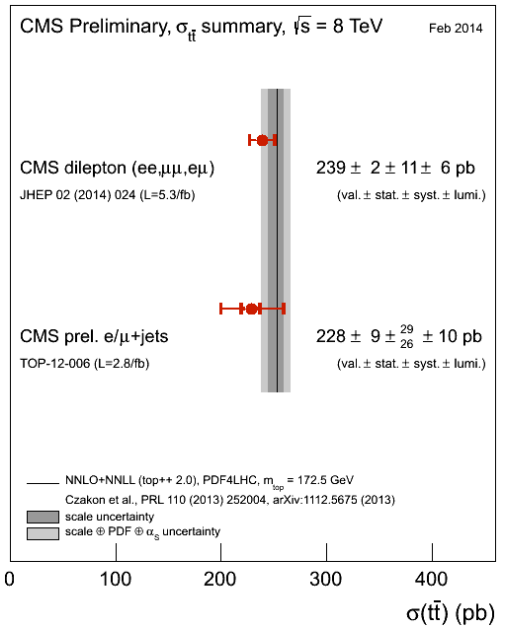
- All measurements are in agreement with NNLO calculations











$t\bar{t}$: LHC combination

- Combined cross section, to be updated with latest results:
- $\sigma_{t\bar{t}} = 173.3 \pm 2.3(\text{stat.}) \pm 7.6(\text{syst.}) \pm 6.3(\text{lumi.})$ pb
  $= 173.3 \pm 10.1$ pb

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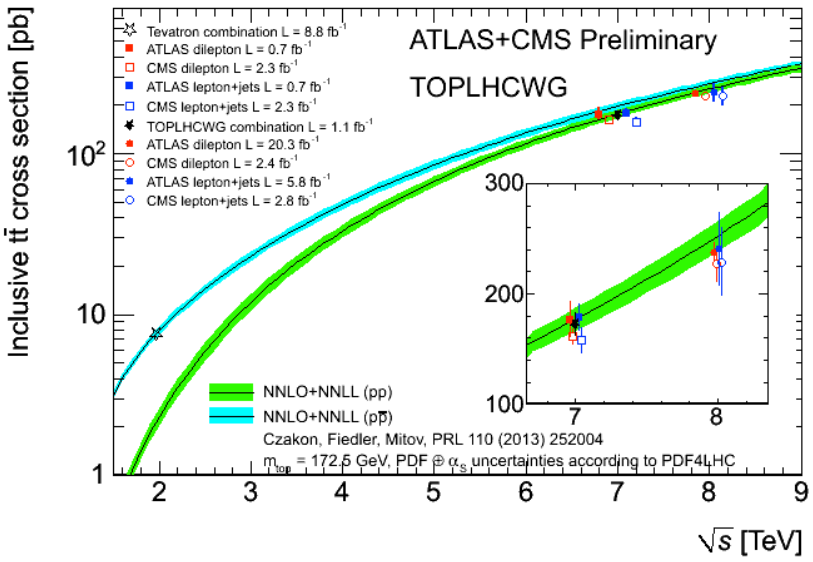

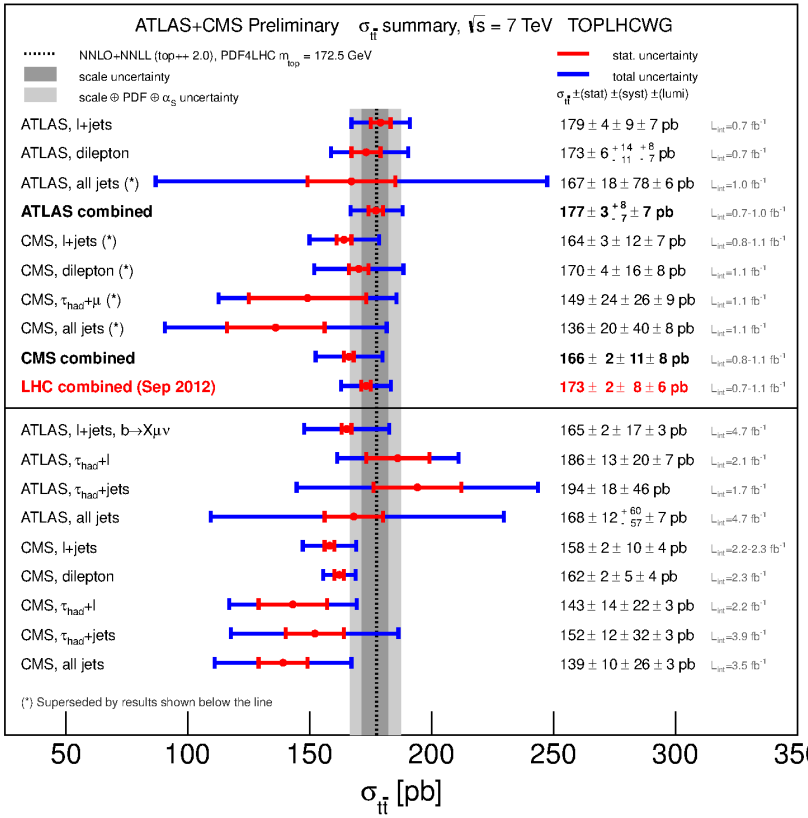

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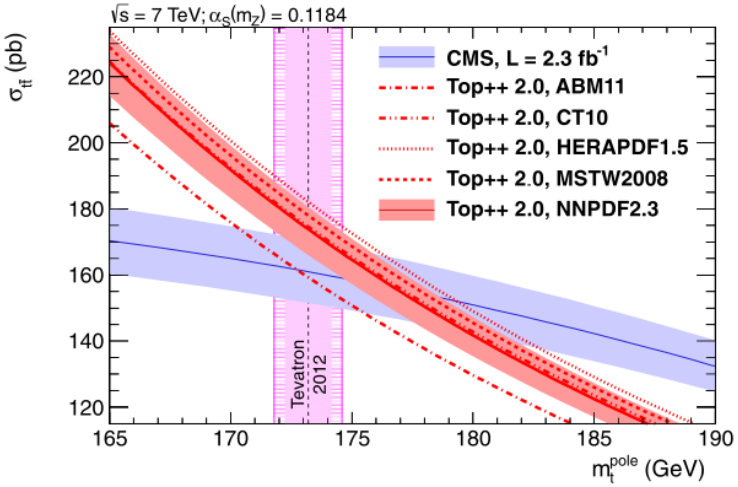
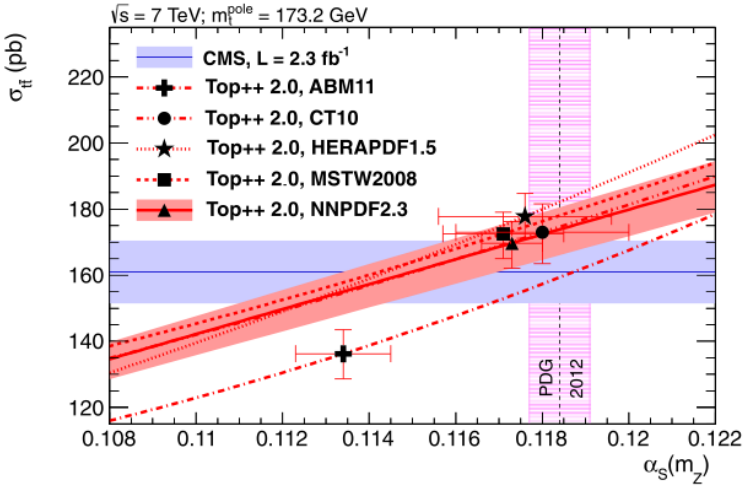
α_s and m_t from cross section

- Turning cross-section dependence on α_s and m_t into measurements
- Based on the most precise CMS measurement at 7 TeV in the dilepton chanel (JHEP 211(2012)067):
- $m_t^{pole} = 176.6^{+3.8}_{-3.4}$ GeV
- $\alpha_s(m_Z) = 0.1151^{+0.0033}_{-0.0032}$





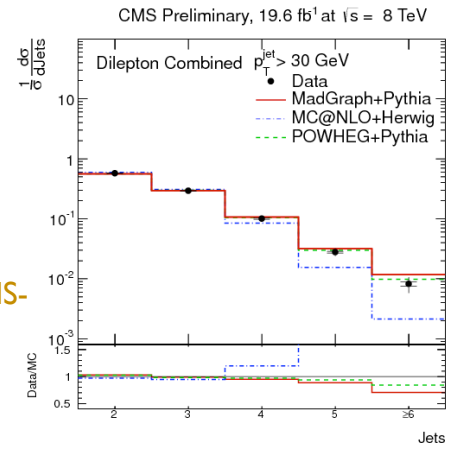
$t\bar{t}$+jets

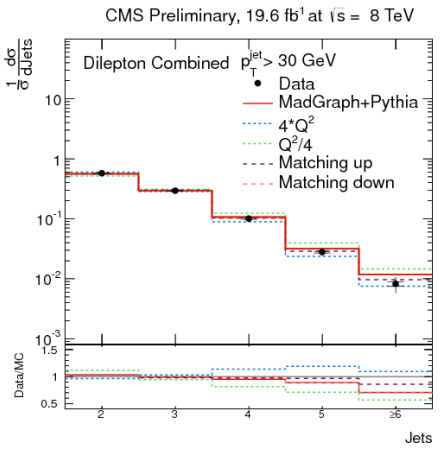
7 TeV, dilepton: ATLAS-2fb^{-1}, EPJC(2013)72-2043, CMS-PAS-TOP-12-023; l+jet: ATLAS-CONF-2012-155, CMS-PAS-TOP-12-018

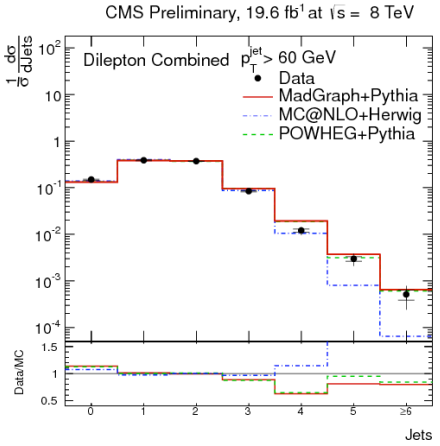
8 TeV, dileptons: CMS-PAS-TOP-12-041

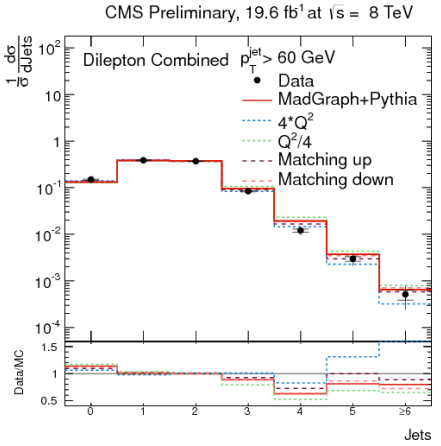
- Distributions compared to different simulation models and parameterization
- Reasonable agreement found with MadGraph, PowHeg, AlpGen, while MC@NLO +Herwig showering predicts lower jet multiplicity than observed
- ATLAS also measured the inclusive $t\bar{t}$+jets cross section (p_T>25 GeV, $|\eta|$<2.5), largely dependent on MC generator:
  - $\sigma(t\bar{t}j)/\sigma(t\bar{t}) = 0.54 \pm 0.01(\text{stat})^{+0.05}_{-0.08}(\text{syst})$

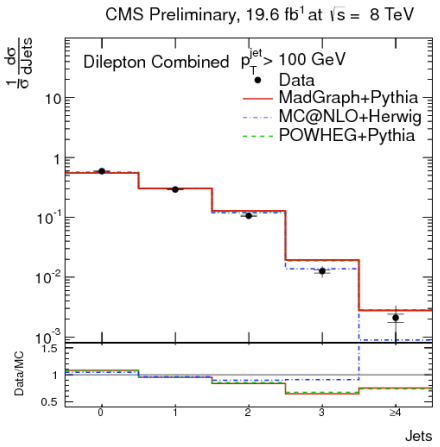
ATLAS-CONF-2012-083 (7 TeV)

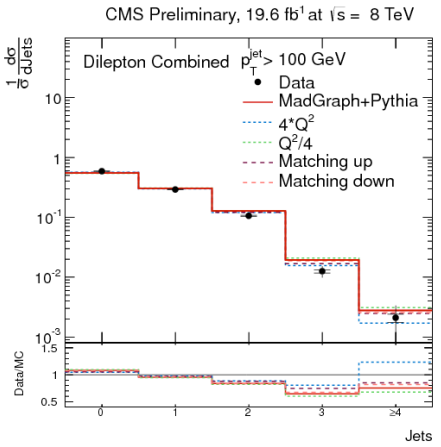












Gap fraction

- Distribution of event fraction without additional jets above a threshold on jet p_T or $H_T = \Sigma_j p_T$
- Compare to different generators or different radiation parameterization:
  - ISR/FSR (ATLAS)
  - Factorization/renormalization scale (CMS)
  - Data within uncertainties, but band ~2x the experimental precision