Precision measurements of the Top quark with the ATLAS experiment

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on behalf of the ATLAS collaboration

Heavy Quarks and Leptons 2014
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Outline

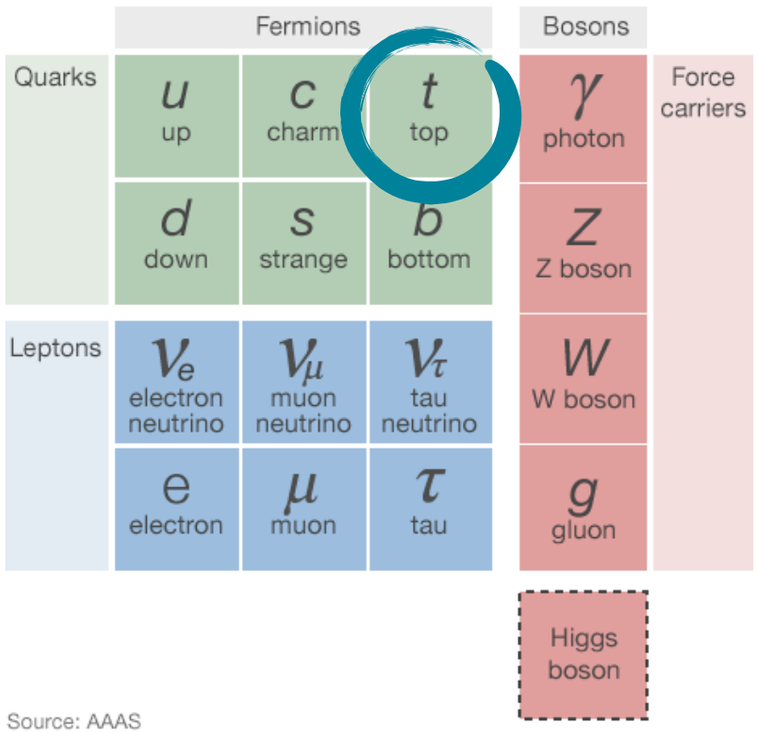
- **Introduction**
- **Motivation**
- **Production Mechanisms**
- **Precision Measurements of the Top Quark:**
    - Production Cross Sections:
        - Top Quark Pair Production
        - Single-Top Quark Production
    - Top Mass
    - Polarization and Spin Correlations
    - W Polarization in Top Decays
    - Electric Charge
    - Charge Asymmetries
    - Vtb
    - Top Quark Couplings to Gauge Bosons
- **Conclusions**

for more detailed information check ATLAS top quark physics results website: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults

The Top Quark

- First observed in 1995 by CDF and D∅ (Tevatron);

[F Abe et al,PRL,74:2626-2631,1995; S. Abachi et al,PRL,74:2632-2637,1995]



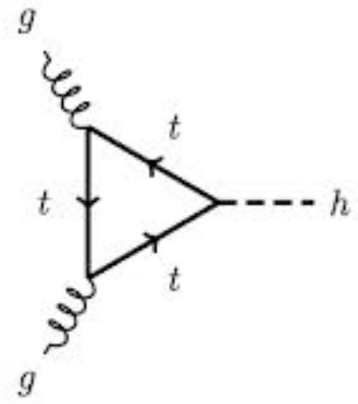
- Completes the 3 family structure of SM;
- Electric charge = 2/3|e|, Spin = 1/2;
- Mass ~ 173.34 ± 0.76 GeV [arXiv:1403.4427 [hep-ex]];
- Fast decay: $\tau \sim 4\times10^{-25}$ s ; $\Gamma = 1.42$ GeV;
- Dominant decay to t → Wb:

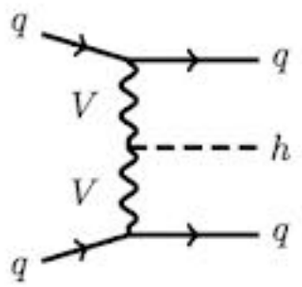
  $|V_{tb}| > 0.999 \Rightarrow BR(t \to Wb) \sim 1$

  BR(t → sW) ≤0.18%
  BR(t → dW) ≤0.02%

Why the Top Quark ?

- **Heaviest of All Fundamental Particles in the Standard Model**:
  - Largest Mass ➙ Largest Coupling to SM Higgs





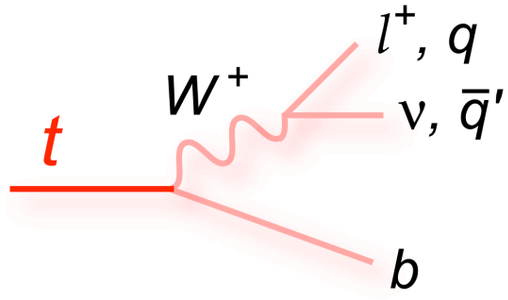
- m_{Top} must be a fundamental parameter in the SM!
- Allows for Self-Consistency Checks of SM Post Higgs Discovery
- Top Quark Mass ~ EW Symmetry Breaking Scale

- **Top Quark Events are Significant Background:**

  e.g. $H \to b\bar{b}\,; H \to WW\,; t\bar{t}H \text{ with } H \to b\bar{b}$

  Better understanding of Top ➙ Better results in these analyses!

- **Short Lifetime (~10^{-25}s):**



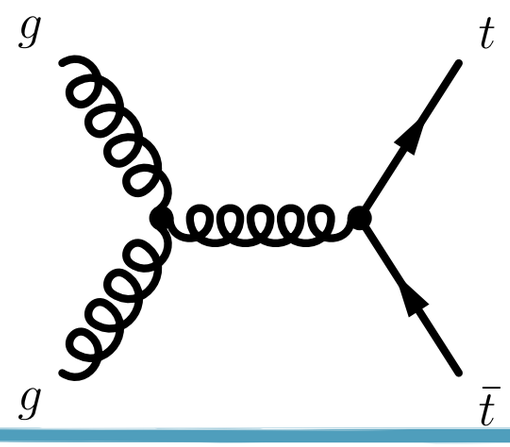
  Allows reconstruction of bare quarks before hadronization - unique among the quarks!

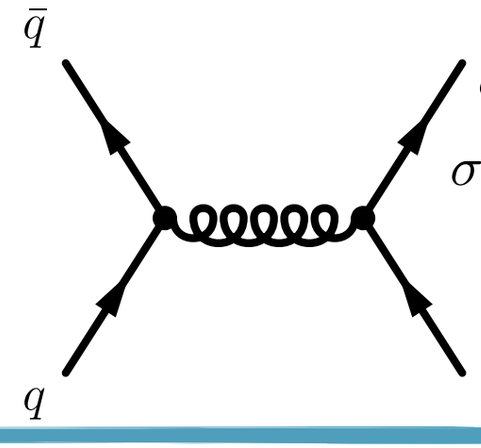
- **Hints of New Physics?**
  Enhanced coupling to many new particles

Production Mechanisms

M.Cacciari et al., P.L. B 710 612(2012);
P.Barnreuther et al., P.R.L. 109 132001(2012);
M.Czakon and A.Mitov, J.H.E.P. 1212 054(2012);
M.Czakon and A.Mitov, J.H.E.P. 1301 080(2013);
M.Czakon, P.Fiedler and A.Mitov, P.R.L. 110 252004 (2013).

Top Pair Production



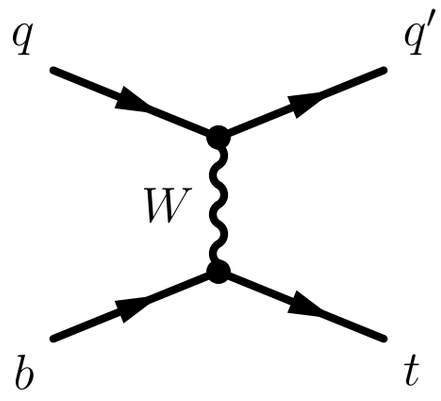


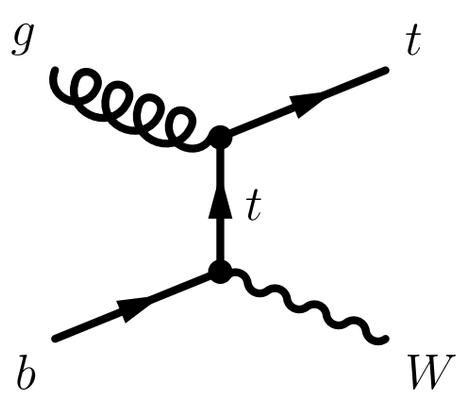
$\sigma_{t\bar{t}}(7\mathrm{TeV}) = 177.3 \pm 9.0^{+4.6}_{-6.0}\mathrm{pb}$

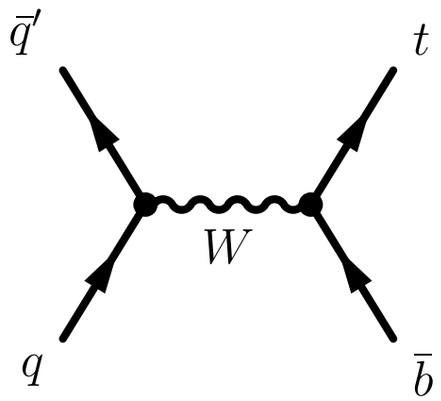
$\sigma_{t\bar{t}}(8\mathrm{TeV}) = 252.9 \pm 11.7^{+6.4}_{-8.6}\mathrm{pb}$

@ NNLO + NNLL

m_{top} = 172.5 GeV







Single Top Production

@ NLO+NNLL

m_{top} = 172.5 GeV

$\sigma_t(\sqrt{s} = 7\ \mathrm{TeV}) = 64.57^{+2.63}_{-1.74}$ pb $\quad \sigma_{Wt}(\sqrt{s} = 7\ \mathrm{TeV}) = 15.74^{+1.17}_{-1.21}$ pb $\quad \sigma_s(\sqrt{s} = 7\ \mathrm{TeV}) = 4.63^{+0.20}_{-0.18}$ pb

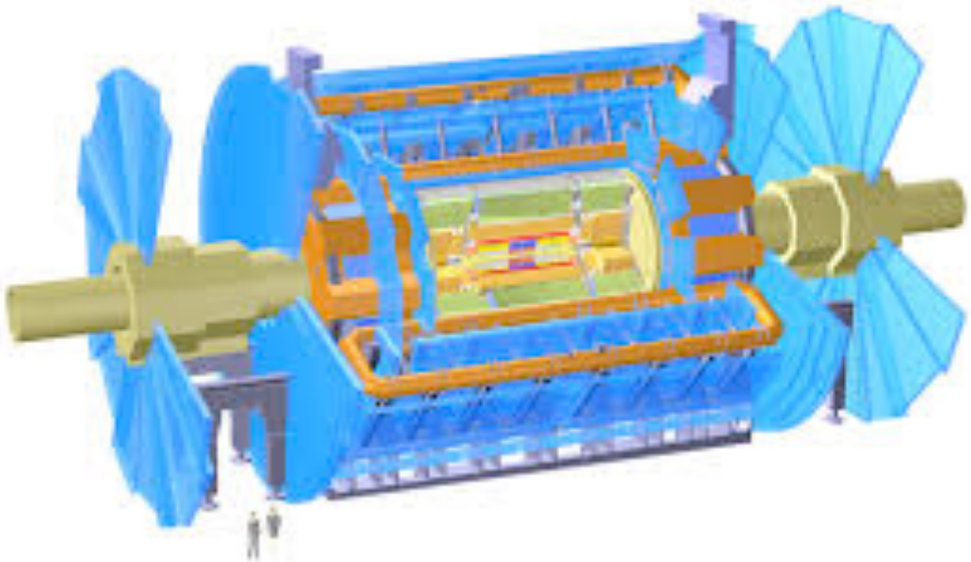
$\sigma_t(\sqrt{s} = 8\ \mathrm{TeV}) = 87.76^{+3.44}_{-1.91}$ pb $\quad \sigma_{Wt}(\sqrt{s} = 8\ \mathrm{TeV}) = 22.37^{+1.52}_{-1.52}$ pb $\quad \sigma_s(\sqrt{s} = 8\ \mathrm{TeV}) = 5.61^{+0.22}_{-0.22}$ pb

N.Kidonakis, P.R. D 83, 091503(R) (2011);
N.Kidonakis, P.R. D 82, 054018 (2010);
N.Kidonakis ,P.R. D 81, 054028 (2010)

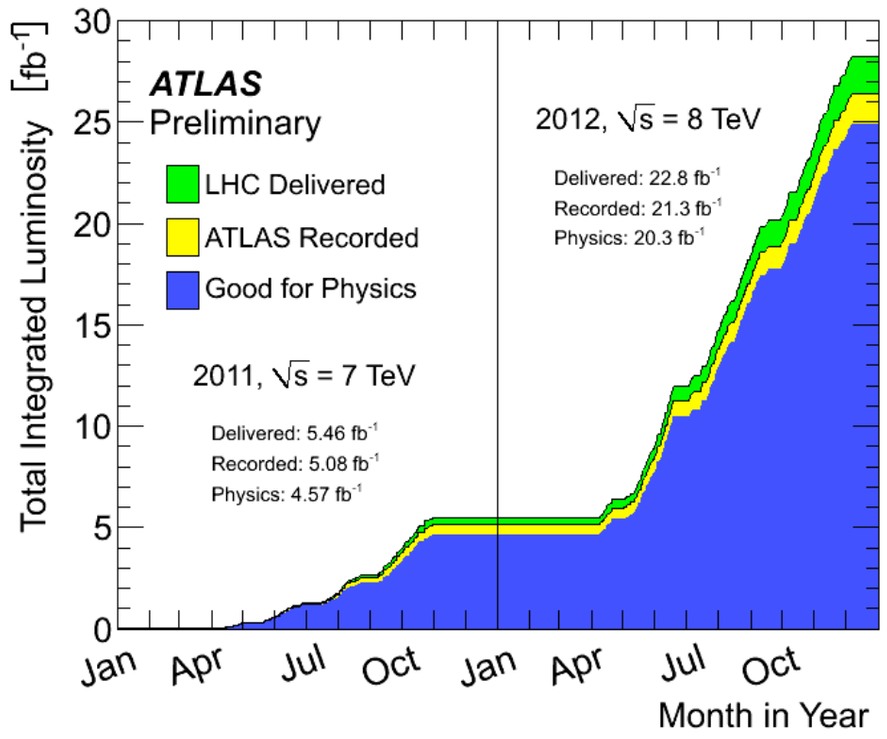
Top Quark Production at the LHC

- At peak instantaneous luminosity @ ATLAS :
  - ~2 top pairs/sec
  - ~1 single top/sec

  were produced during 2012 data-taking!

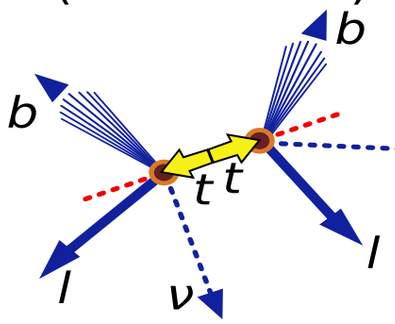


- **Overall ~ 15M top quarks produced in 2011 & 2012!**



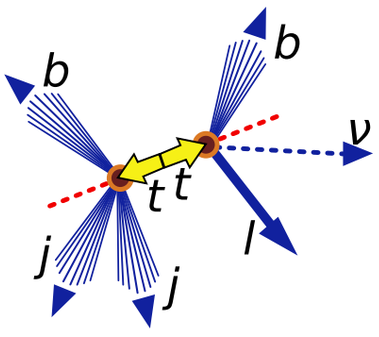
Cross-Section Measurements

- **Top quark pair production ($t\bar{t}$) cross-sections:**
  - Dilepton inclusive cross section measurement (New result)



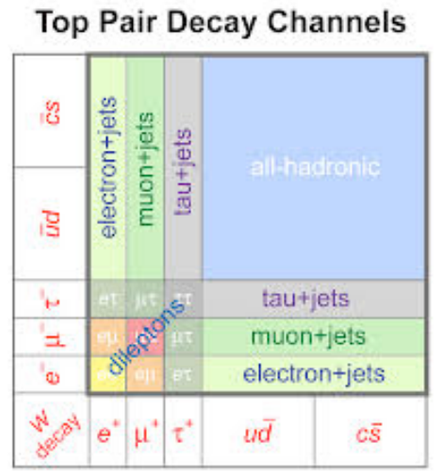
$\sim 30\%$

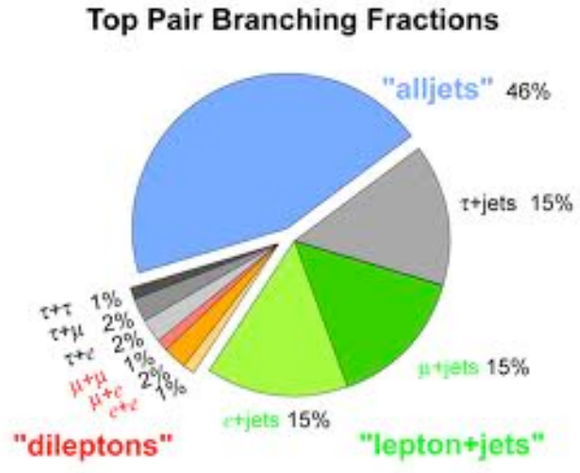
  - Single lepton: Differential cross section measurement



$\sim 5\%$

  - Several Top reconstruction methods: e.g. kinematic likelihood fit





- **Single top quark production cross-sections:**
  - t-channel at 8 TeV (fiducial and inclusive)
  - t-channel at 7 TeV (differential and inclusive) (New result)
  - Wt-channel cross section measurement at both 7 and 8 TeV

Cross-Section Measurements
Top Quark Pair Production ($t\bar{t}$)

- **Dilepton $e\mu$ channel inclusive (7 and 8 TeV Combination)** **NEW**

arXiv 1406.5375 [hep-ex]

Using L = 20.3 fb^{-1} at $\sqrt{s}$=8TeV

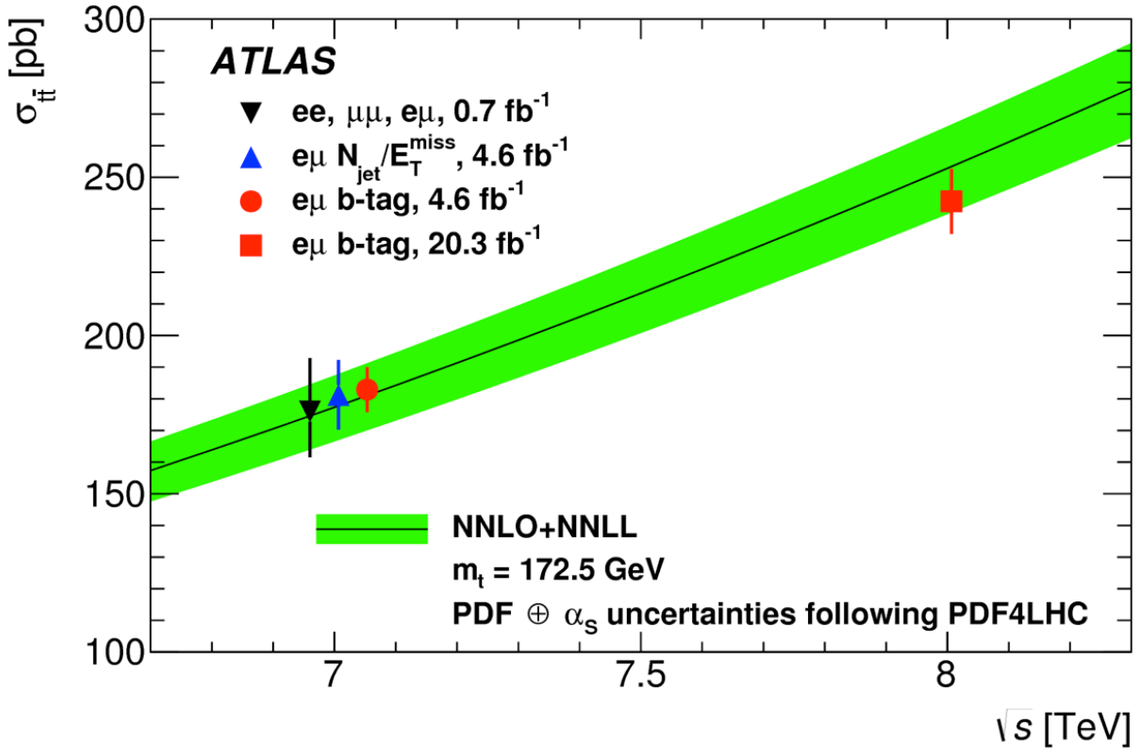
$$\sigma_{t\bar{t}} = 242.4 \pm 1.7(\text{stat.}) \pm 5.5(\text{syst.}) \pm 7.5(\text{lumi}) \pm 4.2(\text{beam en.})\,\text{pb}$$ **4.3%**

Using L = 4.6 fb^{-1} at $\sqrt{s}$=7TeV

$$\sigma_{t\bar{t}} = 182.9 \pm 3.1(\text{stat.}) \pm 4.2(\text{syst.}) \pm 3.6(\text{lumi}) \pm 3.3(\text{beam en.})\,\text{pb}$$ **3.9%**

- Analysis designed to be as least sensitive as possible to systematic uncertainties;

- b-tagging ID/reco/tagging derived from data;

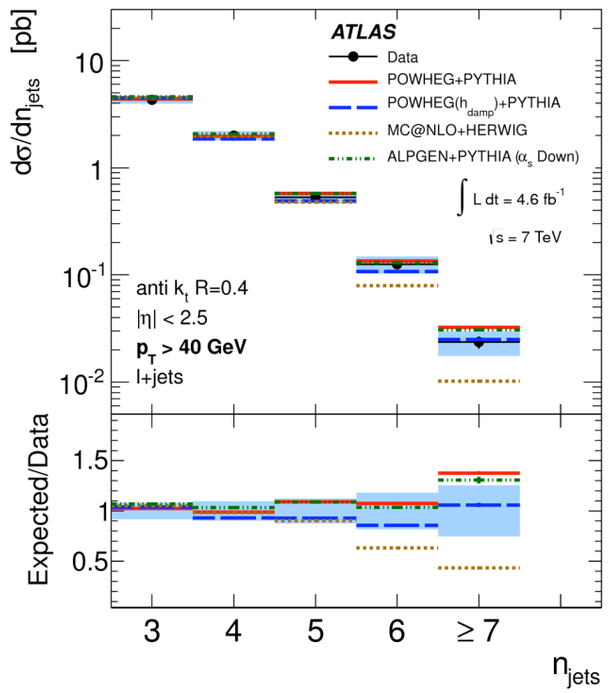


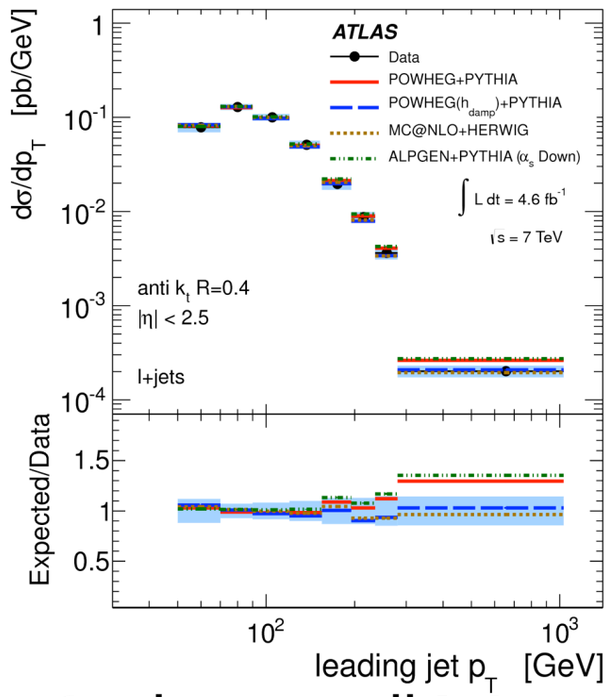
Cross-Section Measurements

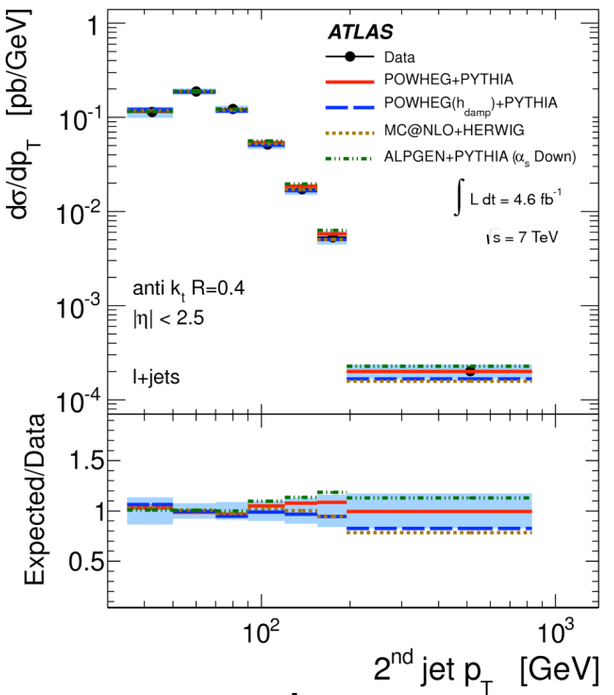
Top Quark Pair Production ($t\bar{t}$)

arXiv:1407.0891

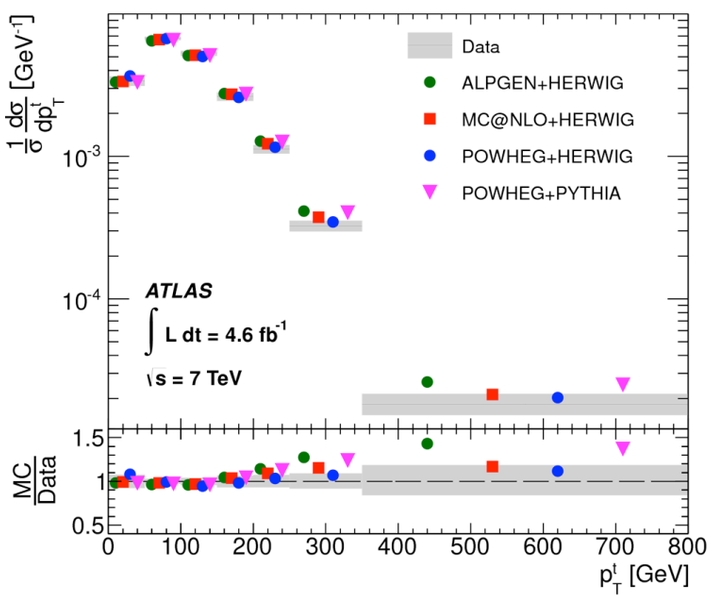
- **Fiducial Differential $\sigma_{t\bar{t}}$ as function of n_{jet} and p_T^{jet} l+jets @ 7 TeV (4.6 fb^{-1})**

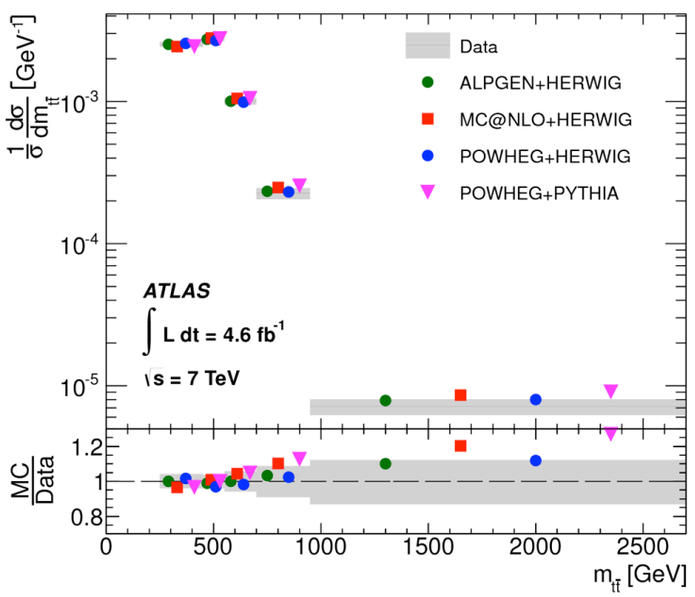


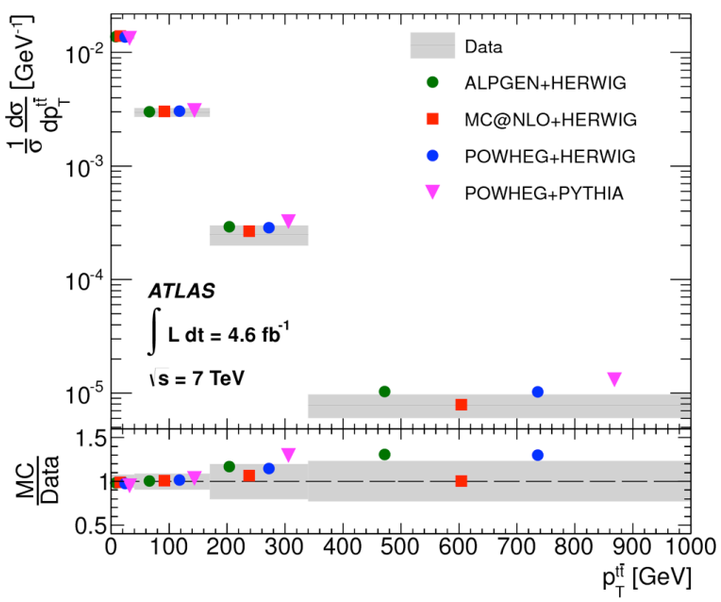




- **Differential $\sigma_{t\bar{t}}$ as function of p_T^t, m_{tt} , p_T^{tt} l+jets @ 7 TeV (4.6 fb^{-1})** arXiv:1407.0371

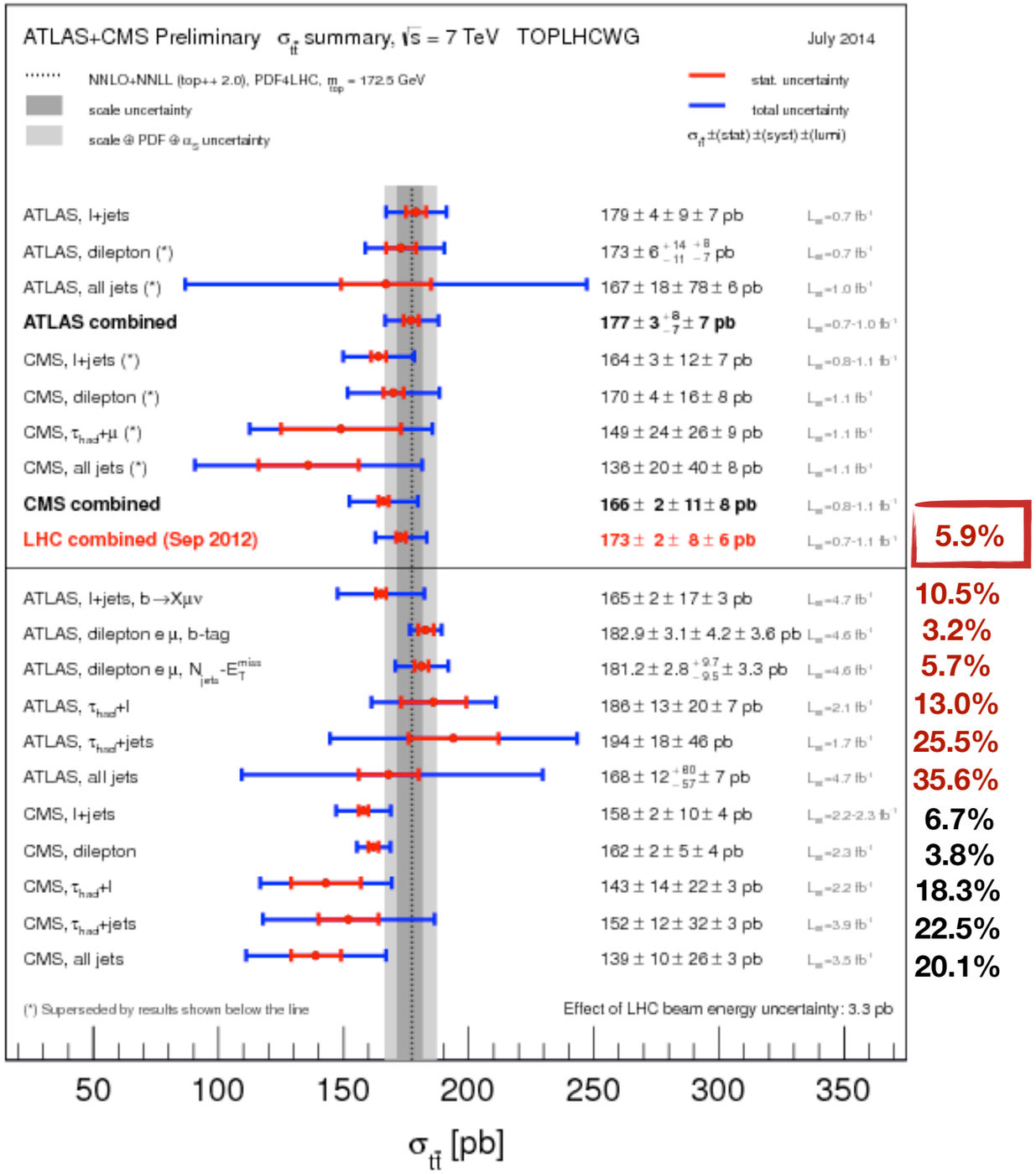


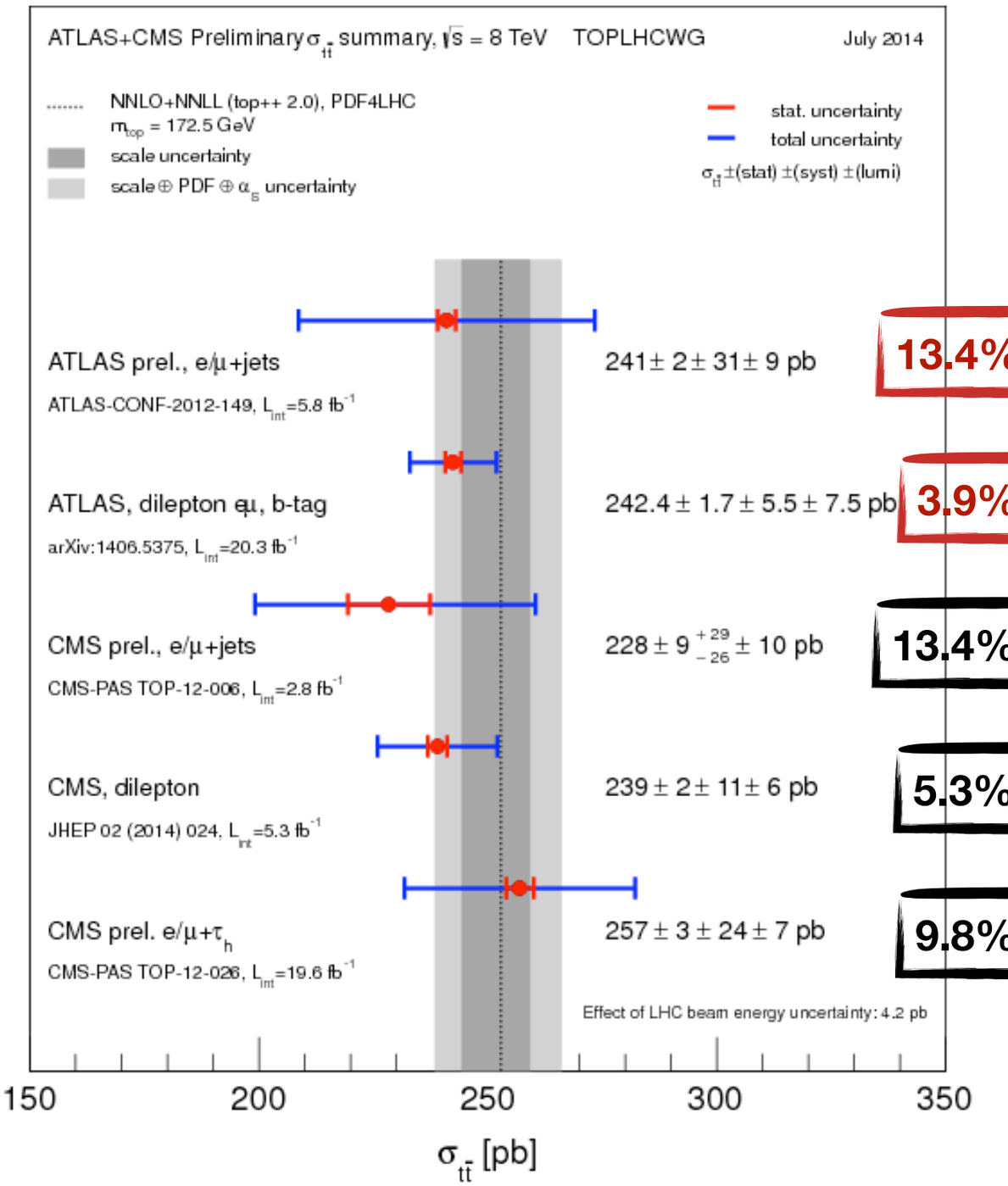




Cross-Section Measurements

Top Quark Pair Production ($t\bar{t}$)



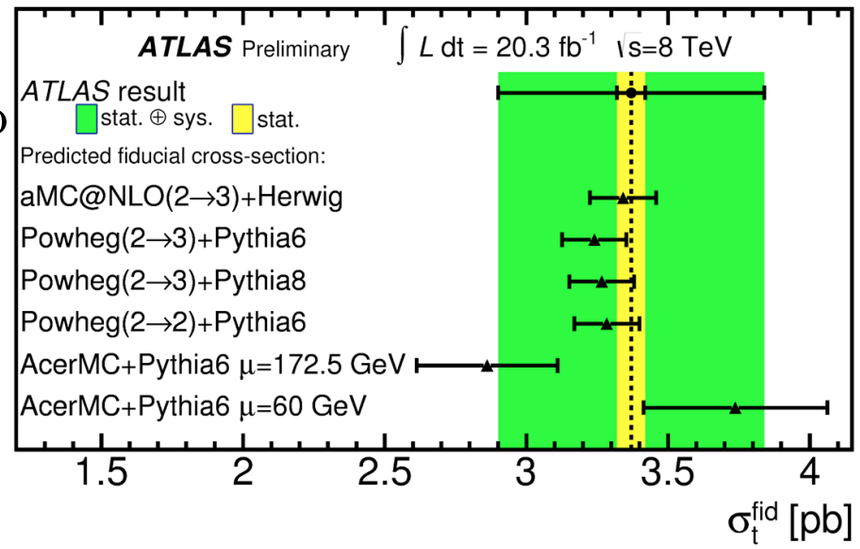


Cross-Section Measurements
Single Top Quark Production: t-channel

- **Cross Section @ 8 TeV (20.3 fb^{-1})**

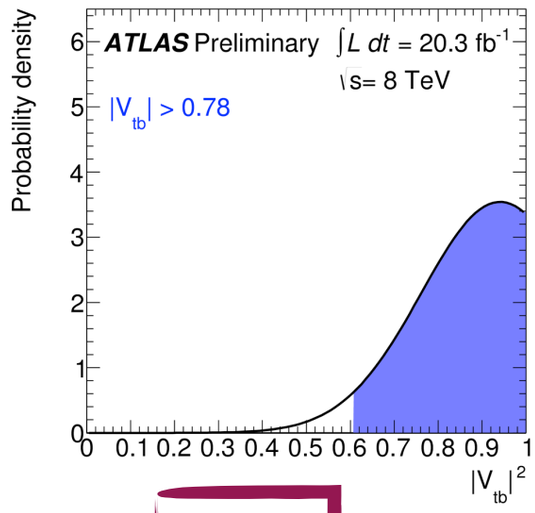
14.6% $\sigma_t = 82.6 \pm 1.2(\text{stat.}) \pm 11.4(\text{syst.}) \pm 3.1(\text{PDF}) \pm 2.3(\text{lumi.})\text{pb}$

ATLAS-CONF-2014-007



- **Assuming CKM matrix obeys $|V_{tb}| \leq 1$ a lower limit is extracted (95% CL):**

Measured: $|V_{tb}| = 0.97^{+0.09}_{-0.10}$

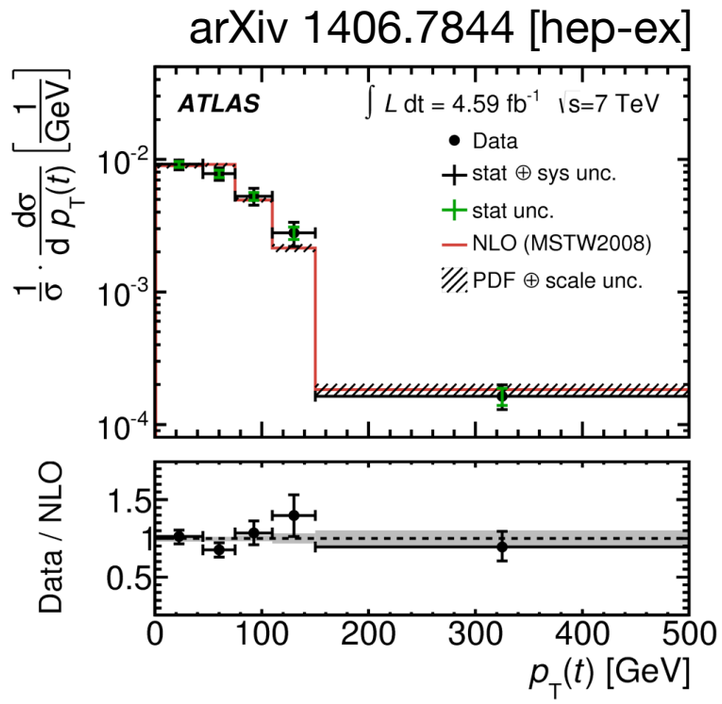


- **Cross Section @ 7 TeV (4.59 fb^{-1})** **NEW**

$\sigma_{tq} = 46 \pm 1(\text{stat.}) \pm 6(\text{syst.})\,\text{pb}$ **(13.2%)**

$\sigma_{\bar{t}q} = 23 \pm 1(\text{stat.}) \pm 3(\text{syst.})\,\text{pb}$ **(21.7%)**

arXiv 1406.7844 [hep-ex]



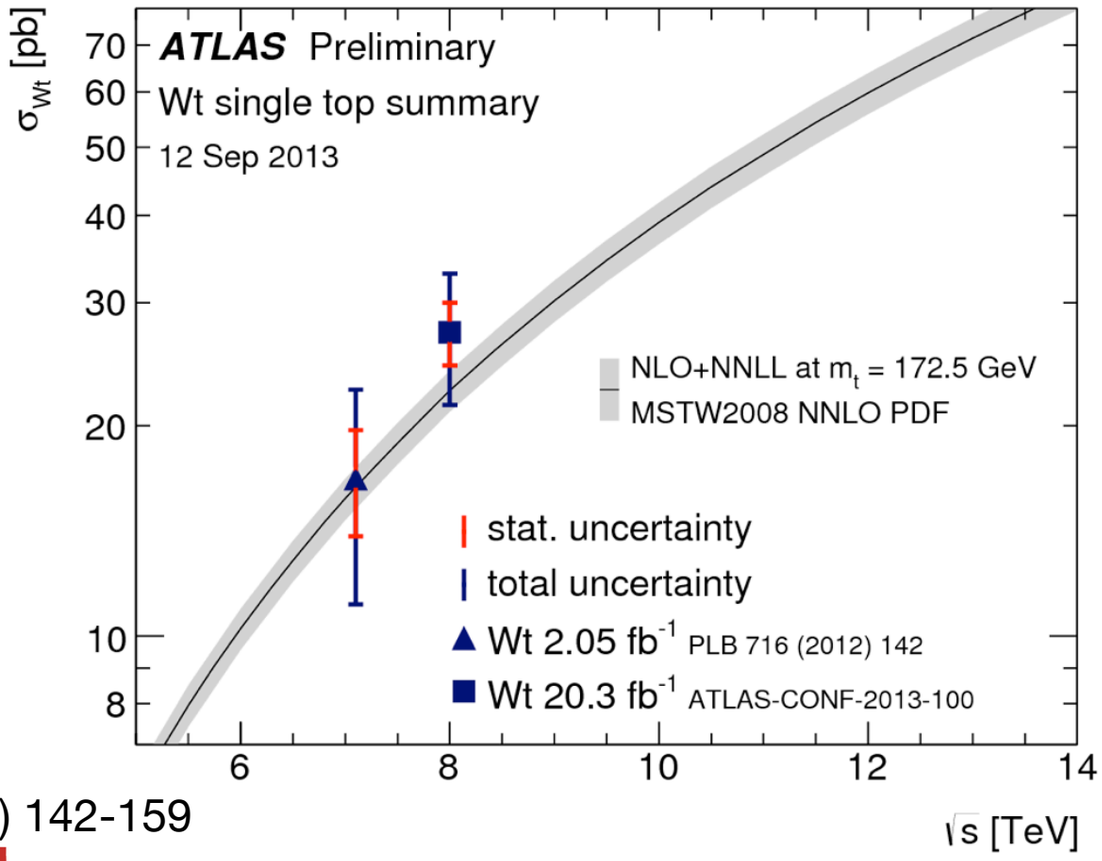
11.8% $\sigma_{(tq+\bar{t}q)} = 68 \pm 8\,\text{pb}$ consistent w/ SM expectation (m_t = 172.5GeV)

- **Using σ(tq + $\bar{t}$q) to its theoretical prediction and assuming $|V_{tb}| \gg |V_{ts}|$:** Measured: $|V_{tb}| = 1.02 \pm 0.07$

Cross-Section Measurements
Single Top Quark Production: Wt-channel

- **Cross Section @ 8 TeV (20.3 fb^{-1})** ATLAS-CONF-2013-100

$\sigma_{Wt} = 27.2 \pm 2.8(\text{stat.}) \pm 5.4(\text{syst.})\,\text{pb}$ **22.4%**



- **|V$_{tb}$| measurement assuming:**
  - The Wtb interaction is left-handed;
  - Wt-channel production & top quark decay through |V$_{ts}$| and |V$_{td}$| << |V$_{tb}$| ;
  - The decay to a possible 4th generation quark is kinematically forbidden;

a lower limit is extracted: $|V_{tb}| > 0.72 \ @\, 95\%\,\text{CL}$

- **Cross Section @ 7 TeV (2.05 fb^{-1})** PLB 716 (2012) 142-159

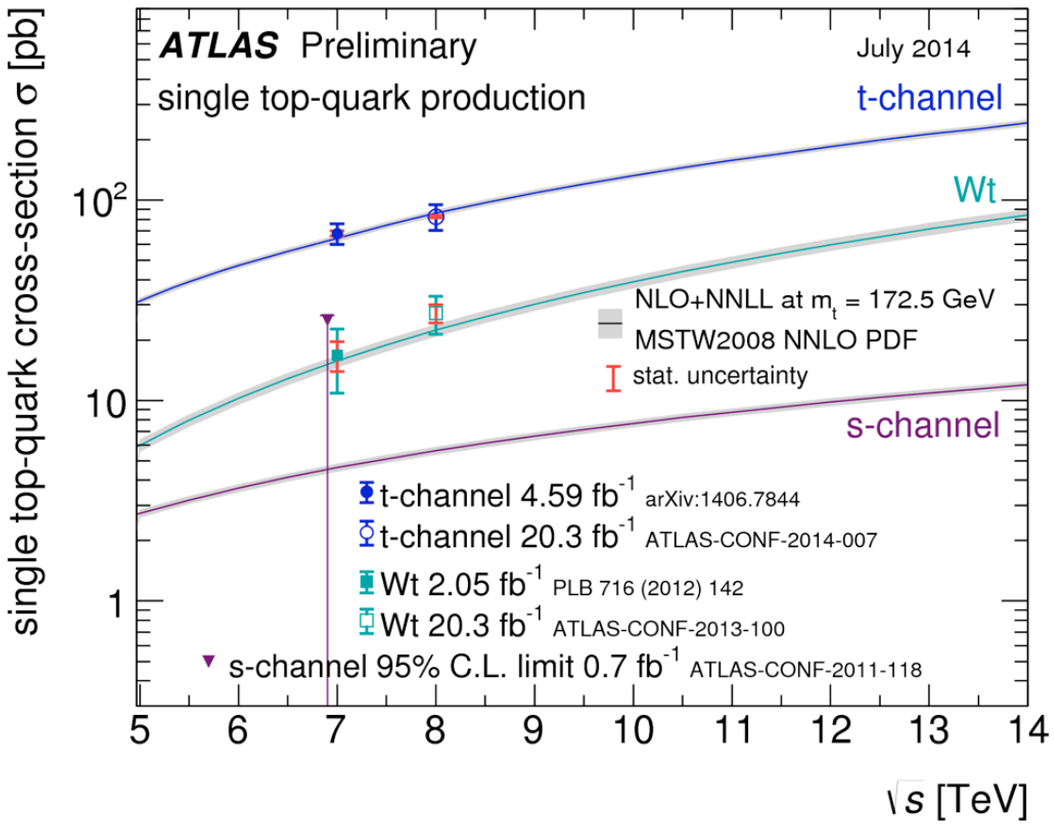
$\sigma_{Wt} = 16.8 \pm 2.9(\text{stat.}) \pm 4.9(\text{syst.})\text{pb}$ **33.9%**

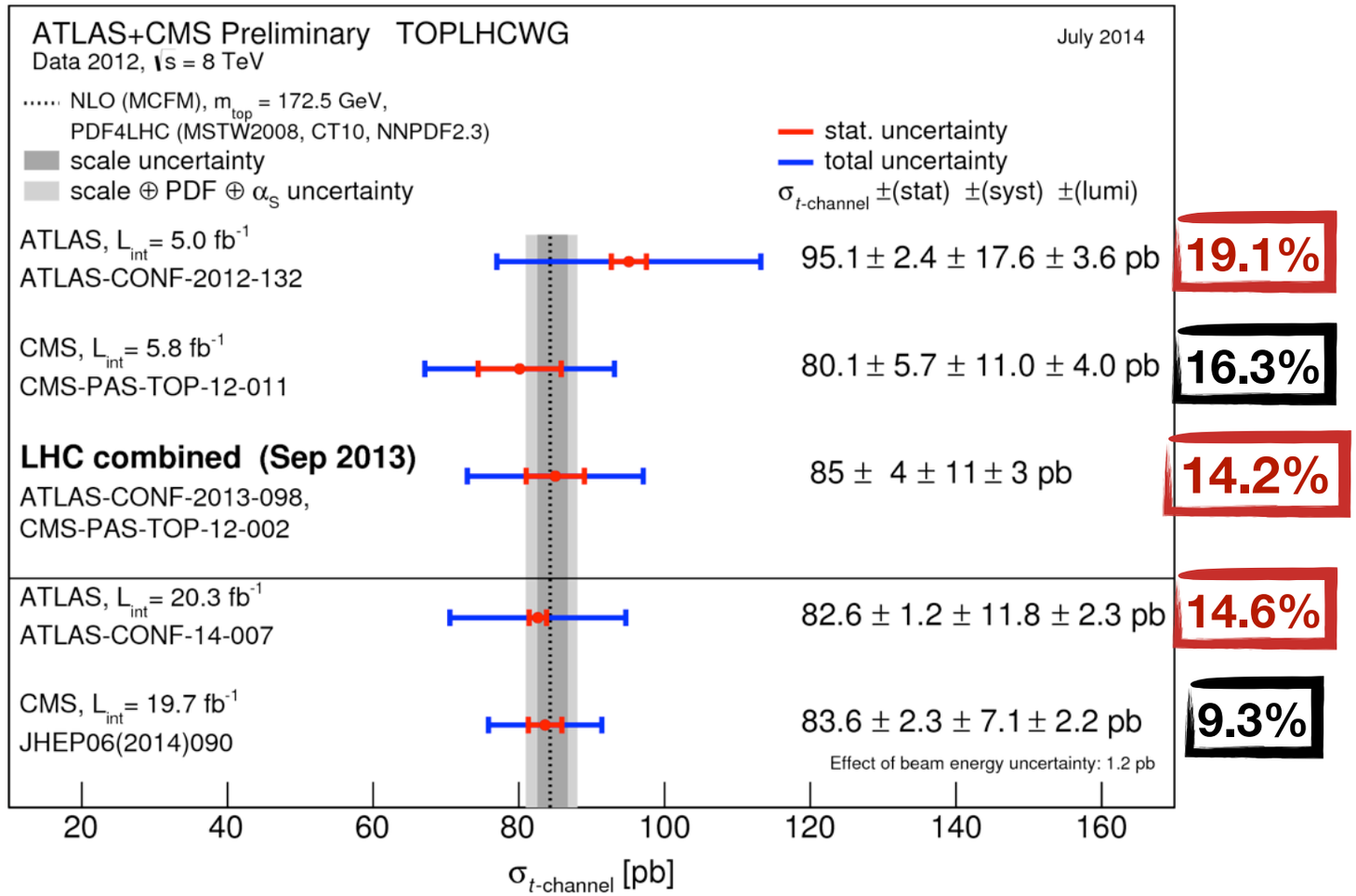
- **Assuming |V$_{ts}$| and |V$_{td}$| are negligible:**

Measured: $|V_{tb}| = 1.03^{+0.16}_{-0.19}$ (using $\sigma_{Wt}^{theory} = 15.7(\pm 1.1) \times |V_{tb}|^2\,\text{pb}$)

Cross-Section Measurements

Single Top Quark Production: Summary



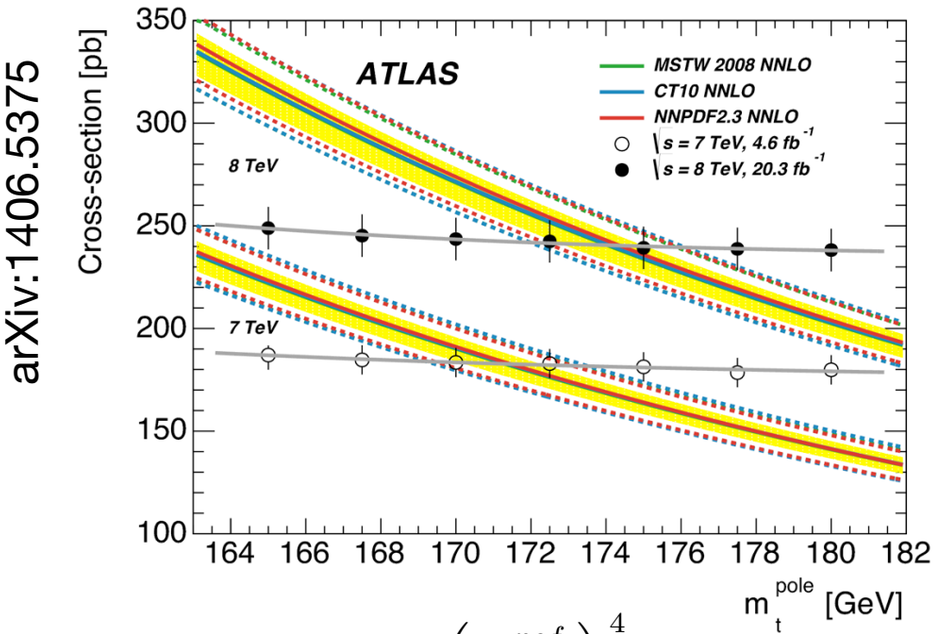


t-channel and Wt: cross-section measurements for 7 TeV and 8 TeV

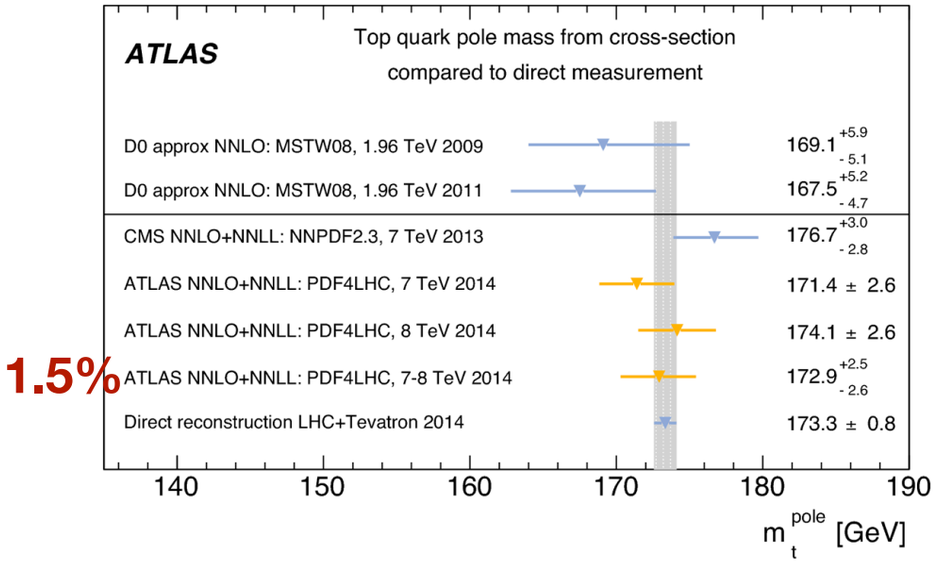
s-channel: upper limit shown

Top Quark Mass

- **Pole Mass determined from:**



$$\sigma_{t\bar{t}}^{theo}(m_t^{ref}) = \sigma(m_t^{ref}) \left(\frac{m_t^{ref}}{m_t^{pole}} \right)^4 (1 + a_1 x + a_2 x^2)$$

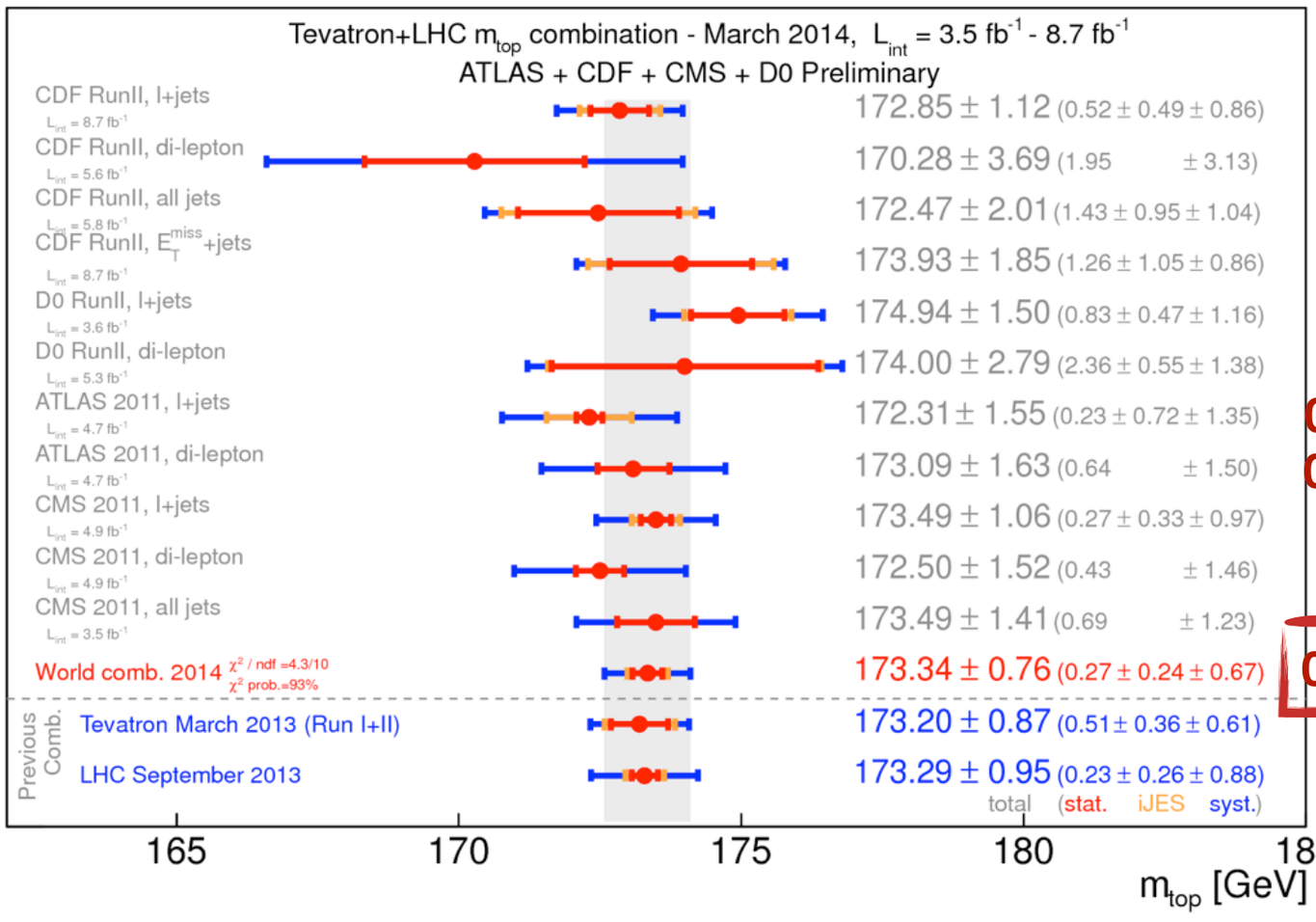


1.5%

- **World combination of Top quark Mass :**

$$m_{top} = 173.34 \pm 0.27(\text{stat.}) \pm 0.71(\text{syst.})\ \text{GeV}$$

0.4%

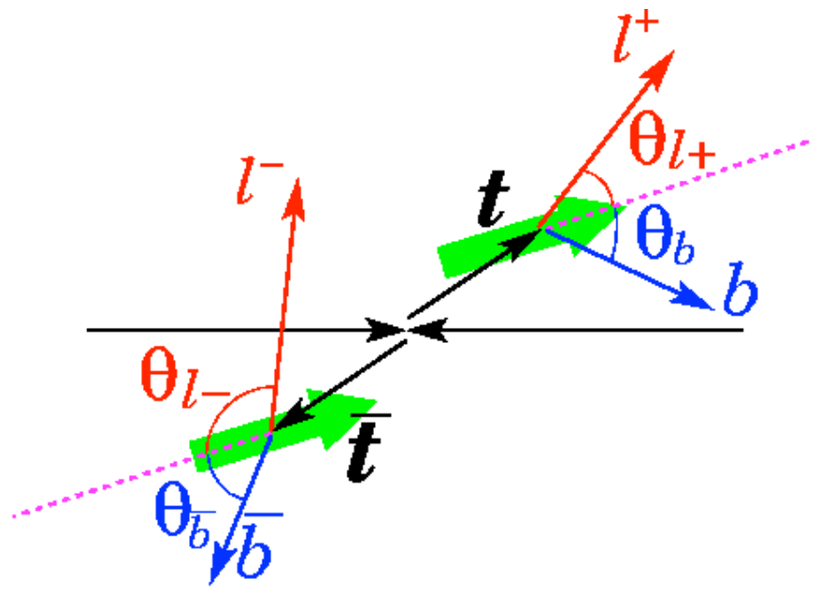


0.9%
0.9%
0.4%

arXiv:1403.4427 [hep-ex]

Polarization and Spin Correlations

- $t\bar{t}$ pairs almost unpolarized in SM, but t and $\bar{t}$ spins are correlated;
- BSM models can affect these properties through either top production or decay;



- Study the angles of the top decay products;

$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta_1 \mathrm{d}\cos\theta_2} = \frac{1}{4}\left(1 + \alpha_1 P_1 \cos\theta_1 + \alpha_2 P_2 \cos\theta_2 - C\cos\theta_1\cos\theta_2\right)$$

$\rightarrow \theta$ is the polar angle of the decay particles

$\rightarrow \alpha$ is the spin analyzing power (~ 1 for charged leptons)

$\rightarrow C$ is the $t\bar{t}$ spin correlation: $C = -A\alpha_+\alpha_-$,
with $A \equiv \frac{N(\uparrow\uparrow)+N(\downarrow\downarrow)-N(\uparrow\downarrow)-N(\downarrow\uparrow)}{N(\uparrow\uparrow)+N(\downarrow\downarrow)+N(\uparrow\downarrow)+N(\downarrow\uparrow)}$

$\rightarrow P_1\,(P_2)$ is the degree polarization of $t\,(\bar{t})$

$$P = \frac{A_P}{2} = \frac{1}{2}\frac{N(\cos\theta_l>0)-N(\cos\theta_l<0)}{N(\cos\theta_l>0)+N(\cos\theta_l<0)}$$

Polarization and Spin Correlations

Polarization of the Top Quark

10.1103/PhysRevLett.111.232002

- **l+jets & dileptonic channels (4.6 fb^{-1} of 7 TeV):**

  extract αP from $\cos\theta_l$ fit on data distribution templates for two scenarios:

  → **CP conserving:** same αP for t and $\bar{t}$

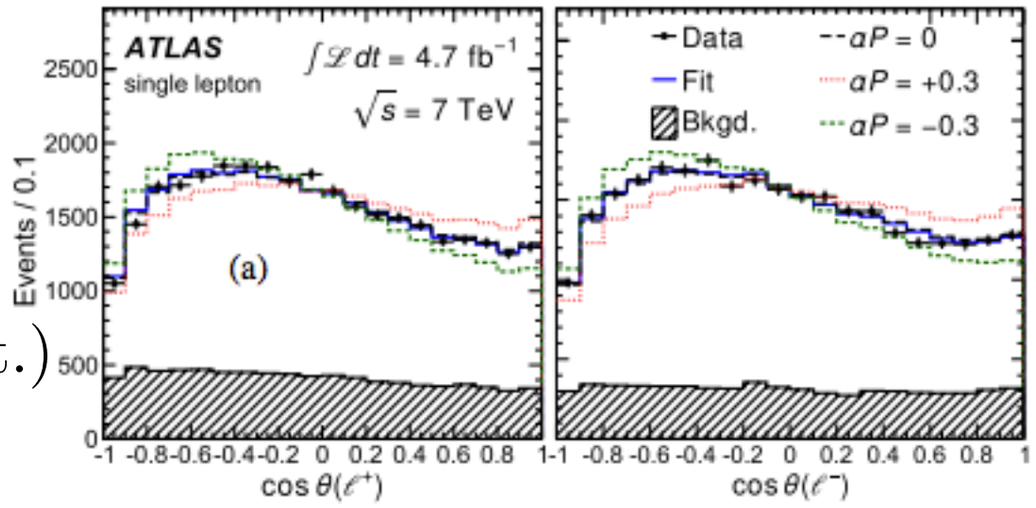
$$\alpha_l \mathrm{P}_{\mathrm{CPC}} = -0.035 \pm 0.014(\mathrm{stat.}) \pm 0.037(\mathrm{syst.})$$

  → **CP violating:** opposite αP for t and $\bar{t}$

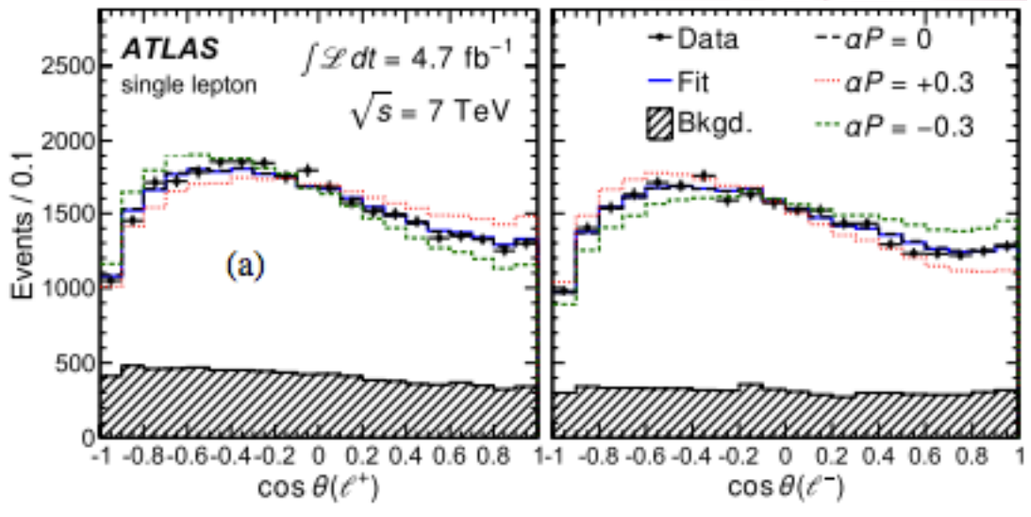
$$\alpha_l \mathrm{P}_{\mathrm{CPV}} = 0.020 \pm 0.016(\mathrm{stat.})^{+0.013}_{-0.017}(\mathrm{syst.})$$

- **No deviation from the SM prediction of negligible polarization is observed for either the CP conserving or maximally CP violating scenario!**

CP Conserving



CP Violating



Polarization and Spin Correlations

Spin Correlations NEW

arXiv:1407.4314 [hep-ex]

- **l+jets & dileptonic channels (4.6 fb^{-1} of 7 TeV):**

  In the SM, the polarization of the pair-produced top quarks in pp collisions is negligible: $$\frac{1}{\sigma}\frac{d\sigma}{d\cos(\theta_+)\mathrm{d}\cos(\theta_-)} = \frac{1}{4}(1 + A\alpha_+\alpha_-\cos(\theta_+)\cos(\theta_-))$$

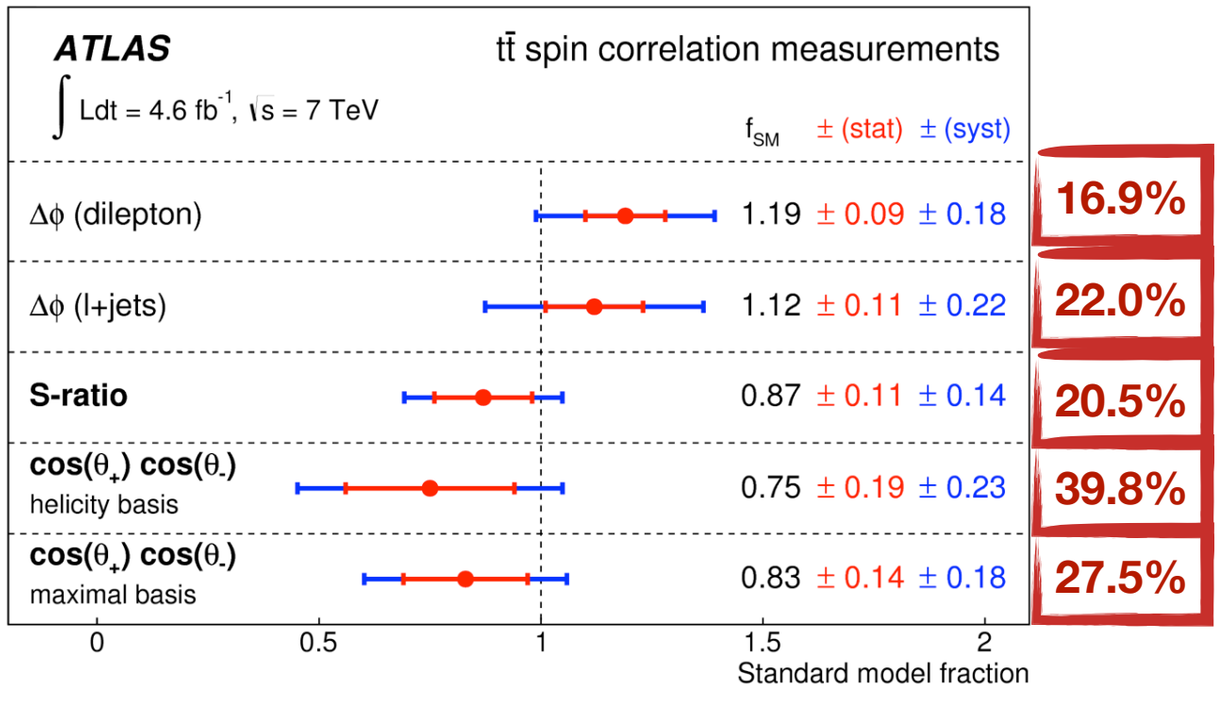
- Analysis performed with 4 observables:

– Δφ between the 2lep. (dilep.) or lep.–jet (W in l+jets)

– The “S-ratio” of matrix elements from the fusion of helicity-like gluons

$$S = \frac{(|\mathcal{M}|^2_{\mathrm{RR}} + |\mathcal{M}|^2_{\mathrm{LL}})_{\mathrm{corr}}}{(|\mathcal{M}|^2_{\mathrm{RR}} + |\mathcal{M}|^2_{\mathrm{LL}})_{\mathrm{uncorr}}} = \frac{m_t^2\{(t\cdot\ell^+)(t\cdot\ell^-) + (\bar{t}\cdot\ell^+)(\bar{t}\cdot\ell^-) - m_t^2(\ell^+\cdot\ell^-)\}}{(t\cdot\ell^+)(\bar{t}\cdot\ell^-)(t\cdot\bar{t})}$$

Requires the full reconstruction of the system.



Basis	$\Delta\phi$	S-ratio	$\cos(\theta_+)\cos(\theta_-)_{\mathrm{helicity}}$	$\cos(\theta_+)\cos(\theta_-)_{\mathrm{maximal}}$
$A^{\mathrm{measured}}_{\mathrm{helicity}}$	$0.37 \pm 0.03 \pm 0.05$	$0.27 \pm 0.03 \pm 0.04$	$0.23 \pm 0.06 \pm 0.10$	—
$A^{\mathrm{measured}}_{\mathrm{maximal}}$	$0.52 \pm 0.04 \pm 0.07$	$0.38 \pm 0.05 \pm 0.06$	—	$0.36 \pm 0.06 \pm 0.09$

$$f_{SM} = \frac{N_{A=SM}}{N_{A=SM} + N_{A=0}}$$

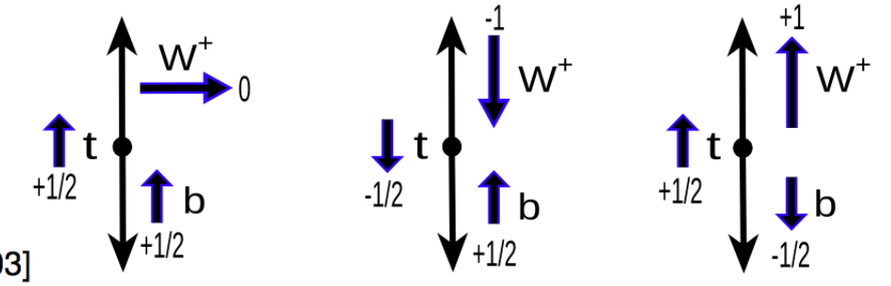
$$A^{\mathrm{measured}}_{\mathrm{basis}} = f_{\mathrm{SM}}\, A^{\mathrm{SM}}_{\mathrm{basis}}$$

W Polarization in $t \to bW$ decays

- **Testing a Standard Model prediction:**
  [Phys. Rev. D 45 (1992) 124]

$$(F_0 + F_L + F_R = 1)$$

[PRD81 (2010) 111503]



longitudinal W — SM (NNLO): $F_0 = 0.687$

left-handed W — $F_L = 0.311$

right-handed W — $F_R = 0.0017$

- **How to measure the W helicity states?**

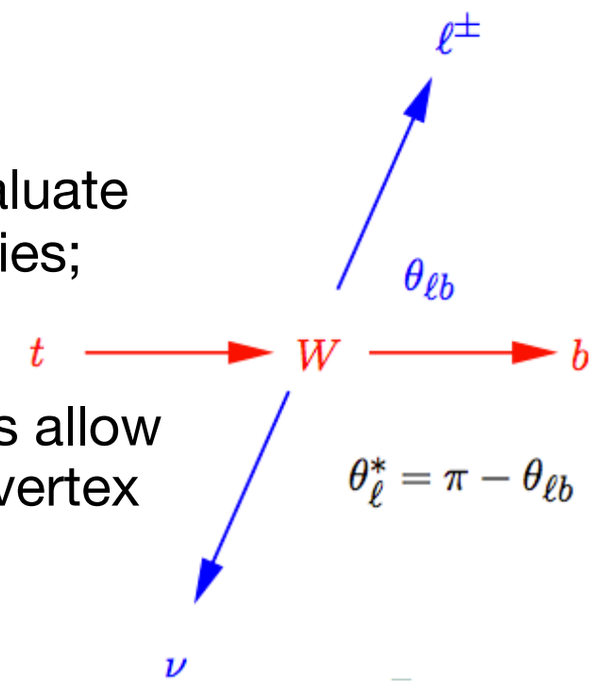
- Full event reconstruction required (l+jets & dilepton);

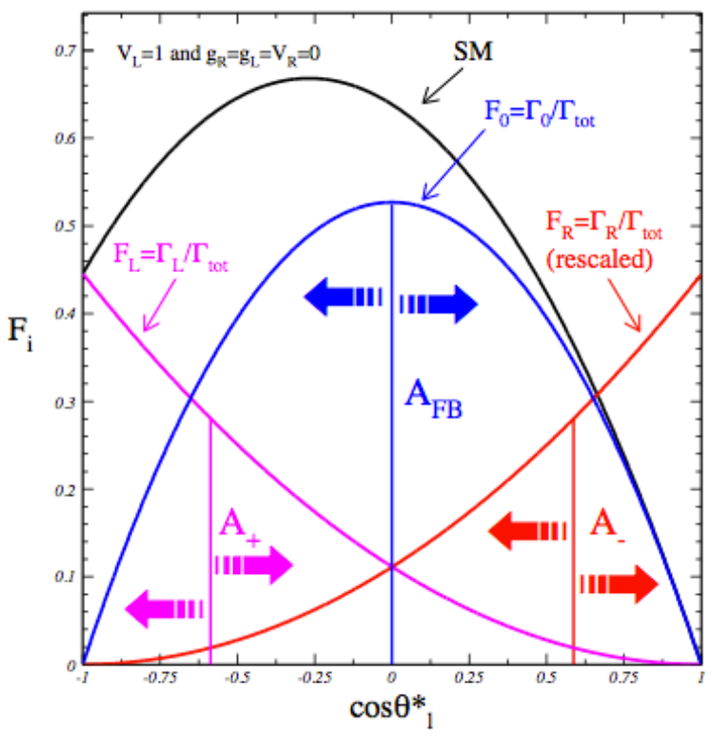
- Fit the $cos\theta^*$ with templates and evaluate angular asymmetries;

- These observables allow to probe the *Wtb* vertex and look for new physics;

$$\frac{1}{N}\frac{dN}{d\cos\theta_\ell^*} = \frac{3}{2}\left[F_0\left(\frac{\sin\theta_\ell^*}{\sqrt{2}}\right)^2 + F_L\left(\frac{1-\cos\theta_\ell^*}{2}\right)^2 + F_R\left(\frac{1+\cos\theta_\ell^*}{2}\right)^2\right]$$

$\theta_\ell^* \rightarrow$ the angle between the ℓ (in *W* rest frame) and the *W* (in *t* rest frame)





Asymmetries (@ NNLO):

$$A_t = \frac{N(\cos\theta_\ell^* > t) - N(\cos\theta_\ell^* < t)}{N(\cos\theta_\ell^* > t) + N(\cos\theta_\ell^* < t)}$$

$A_{FB} = -0.232 \pm 0.004$

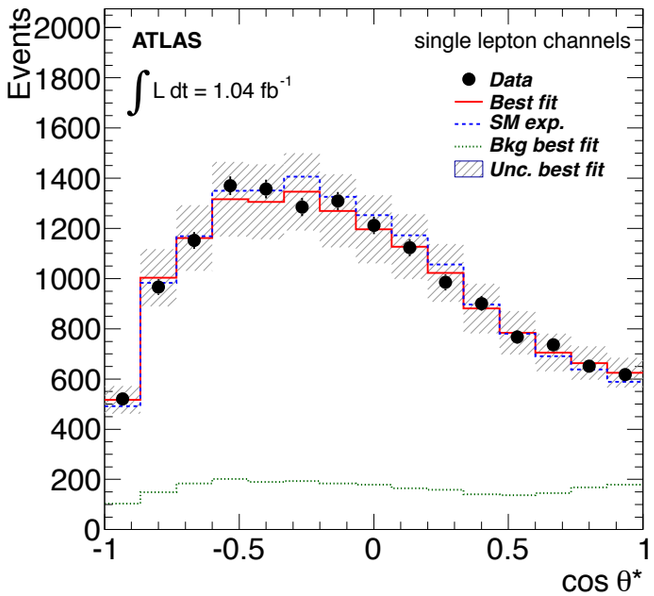
$A_+ = 0.537 \pm 0.004$

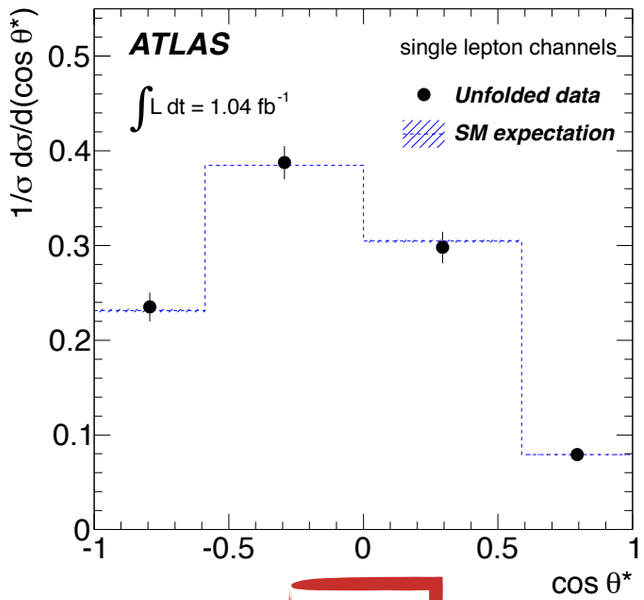
$A_- = -0.841 \pm 0.006$

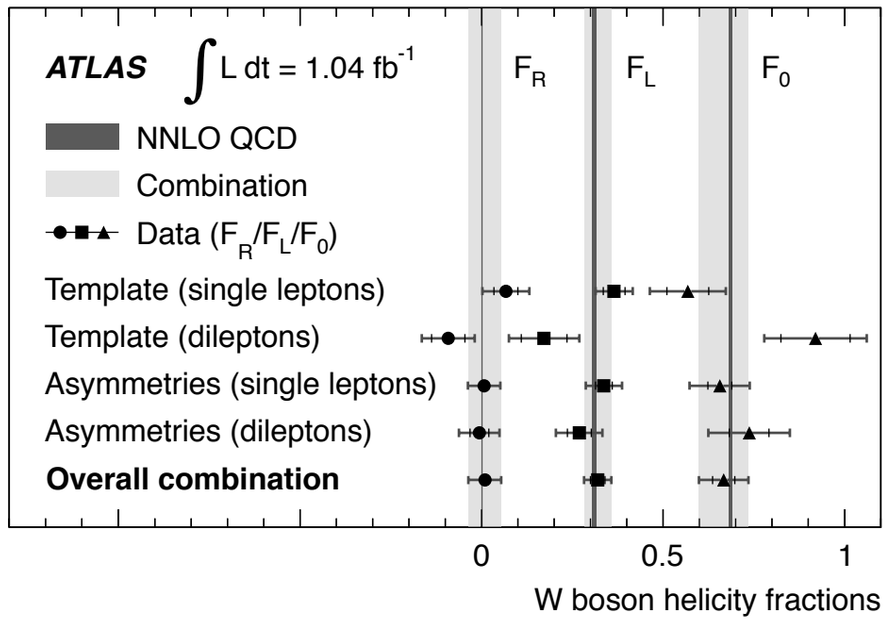
W Polarization in $t \to bW$ decays

- **W helicity states (l+jets & dilepton @ 1.04 fb^{-1}):**

[JHEP 1206 (2012) 088]







$$F_0 = 0.67 \pm 0.03(\text{stat.}) \pm 0.06(\text{syst.})$$ **10%**

$$F_L = 0.32 \pm 0.02(\text{stat.}) \pm 0.03(\text{syst.})$$ **11%**

$$F_R = 0.01 \pm 0.01(\text{stat.}) \pm 0.04(\text{syst.})$$

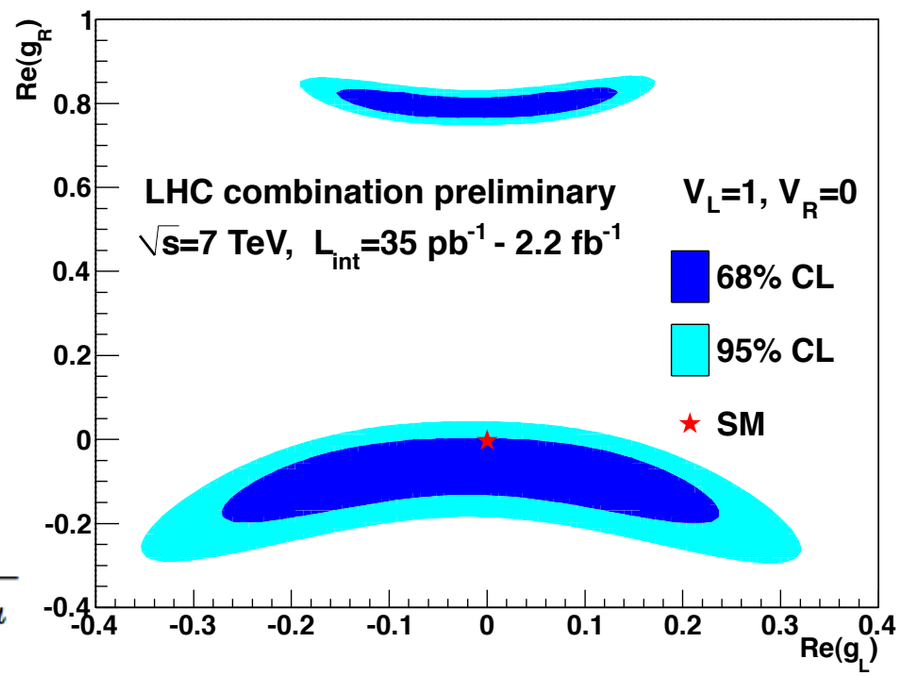
$$A_+ = 0.53 \pm 0.02$$ **3.8%**

$$A_- = 0.84 \pm 0.02$$ **2.4%**

- **General *Wtb* vertex:**

Eur.Phys.J. C50 (2007) 519-533

$$\mathcal{L} = -\frac{g}{\sqrt{2}} \bar{b} \gamma^\mu (V_L P_L + V_R P_R) t W_\mu^- - \frac{g}{\sqrt{2}} \bar{b} \frac{i\sigma^{\mu\nu} q_\nu}{M_W} (g_L P_L + g_R P_R) t W_\mu^-$$

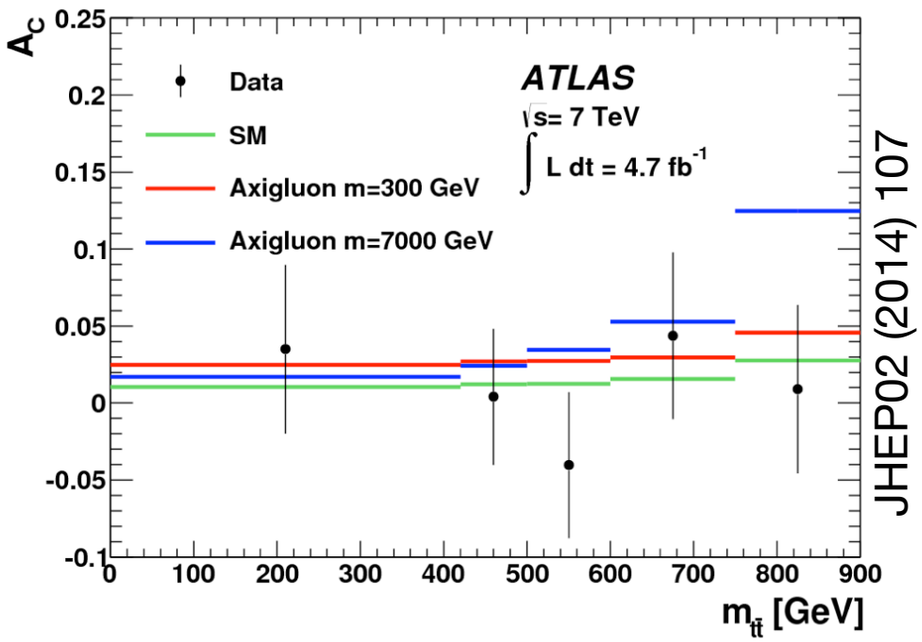


Electric Charge & Charge Asymmetry

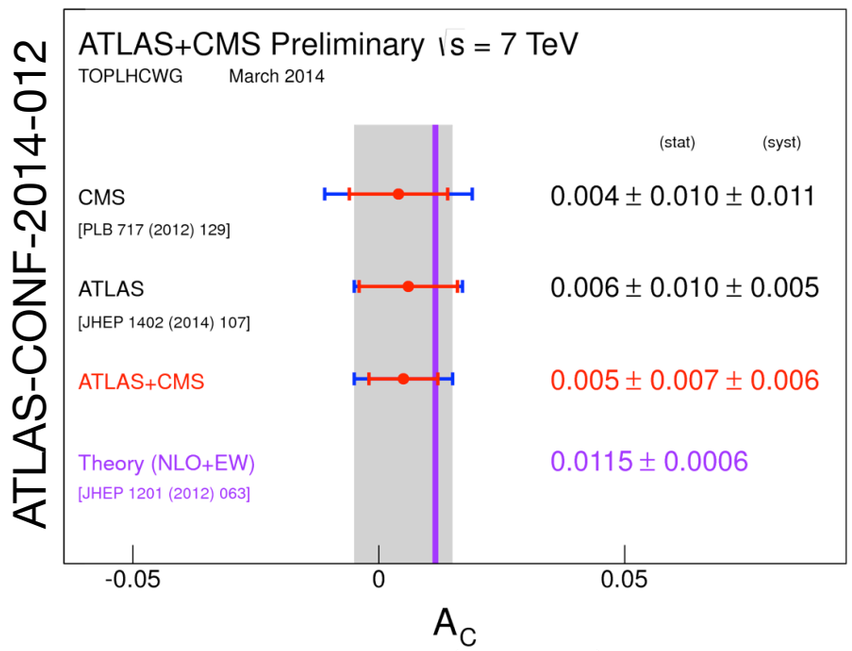
- **Electric Charge Measured @ 7TeV:** JHEP11 (2013) 031

$Q = 0.64 \pm 0.02(stat.) \pm 0.08(syst.)e$ **12.9%** $Q = -\frac{4}{3}e$ excluded at 8σ

- **Charge Asymmetry Measured l-jets @ 7TeV:** $A_C^{t\bar{t}} = \frac{N(\Delta|y|>0) - N(\Delta|y|<0)}{N(\Delta|y|>0) + N(\Delta|y|<0)}$
  - Small charge asymmetry in SM for : $A_C^{SM} = 0.0123 \pm 0.0005$
  - BSM enhancement possible
  - Anomalous A_{FB} measurements at the Tevatron

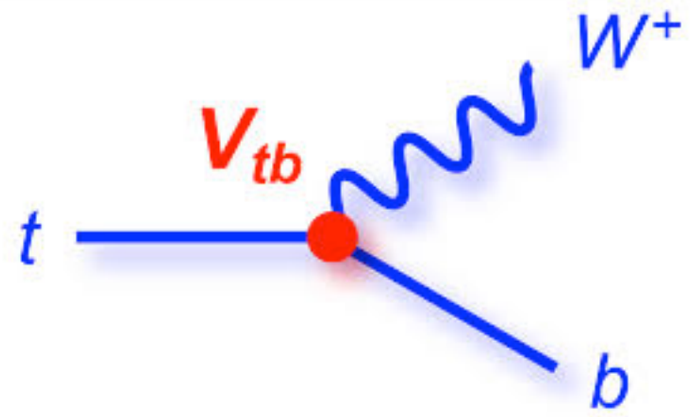


$A_C^{t\bar{t}} = 0.006 \pm 0.010(stat.) \pm 0.005(syst.)$



$A_C^{t\bar{t}} = 0.005 \pm 0.007(stat.) \pm 0.006(syst.)$

V_{tb} Measurements



- Single top quark cross section is powerful to probe V_{tb}
- Allows to test BSM (FCNC in t-channel; W' in s-channel)

- **$|V_{tb}|^2$ is extracted from the observed single top-quark cross section**

$$|V_{tb,\,obs}|^2 = \frac{\sigma_{t,\,obs.}}{\sigma_{t,\,SM}} \times |V_{tb,\,SM}|^2$$

$|V_{tb}| >> |V_{ts}|, |V_{td}|$ single top production through $|V_{ts}|$,$|V_{td}|$ is small;

Single-Top Channel	Measurement	
t-channel @ 7TeV (4.59 fb^{-1}) arXiv 1406.7844 [hep-ex]	$\|V_{tb}\| = 1.02 \pm 0.07$	6.9%
t-channel @ 8TeV (20.3 fb^{-1}) ATLAS-CONF-2014-007	$\|V_{tb}\| = 0.97^{+0.09}_{-0.10}$	9.8%
Wt-channel @ 7TeV (2.05 fb^{-1}) PLB 716 (2012) 142-159	$\|V_{tb}\| = 1.03^{+0.16}_{-0.19}$	17%
Wt-channel @ 8TeV (20.3 fb^{-1}) ATLAS-CONF-2013-100	$\|V_{tb}\| > 0.72$ @ 95% CL	

Top Couplings to Bosons $t\bar{t}V\,(V = \gamma, Z, W, H)$

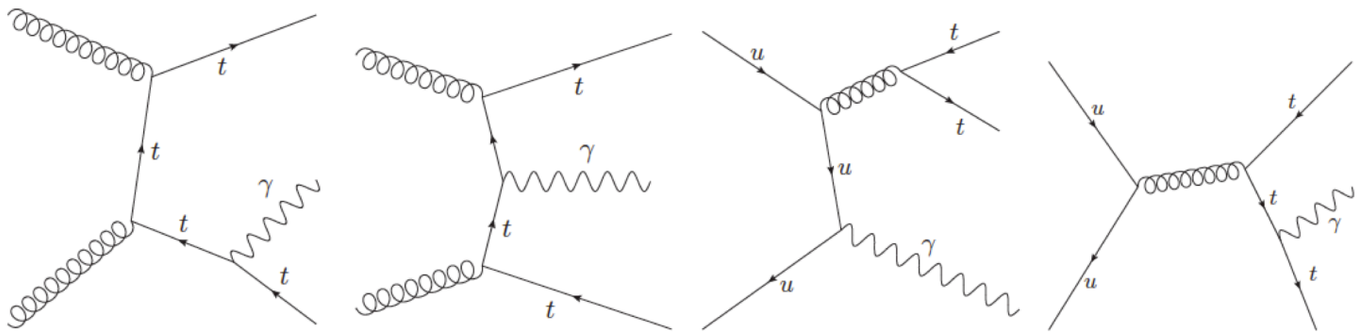
$t\bar{t}\gamma$

ATLAS-CONF-2011-153

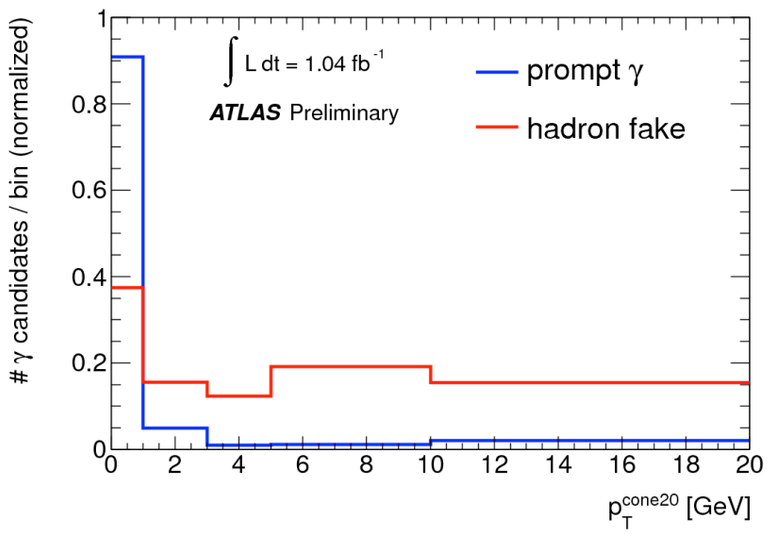
- $t\bar{t}\gamma$ **@ 7 TeV:**

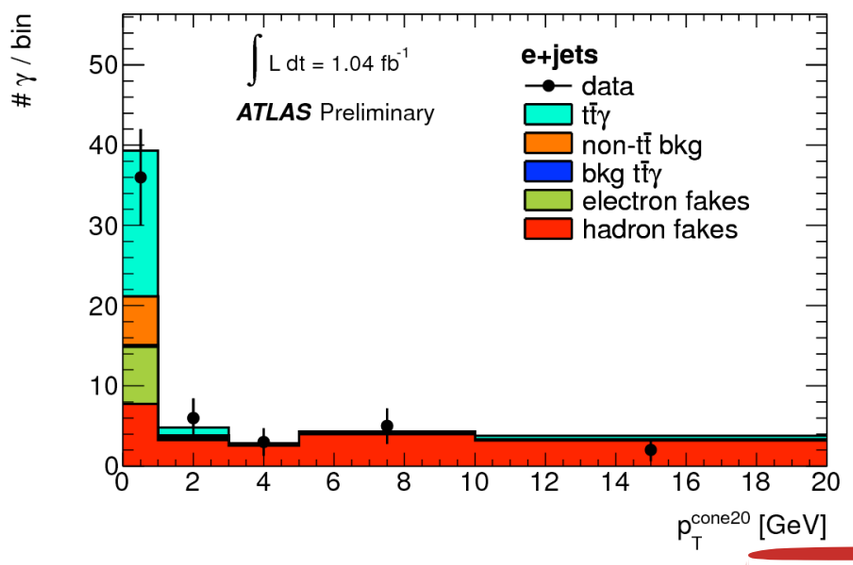
$$\sigma^{theo}_{t\bar{t}\gamma} = 2.1 \pm 0.4\,\mathrm{pb}$$

($p_{T,\gamma} > 8\,\mathrm{GeV}$ @ generator)



- Top quark EW couplings to γ ∝ Q_t
- Event Selection = Lepton+jets channel ⊕ γ with p_T > 15 GeV
- γ isolation used to discriminate prompt from fake γ ⇒ Template Fit to $p_{T,\gamma}$





Measured: $\sigma_{t\bar{t}\gamma} = 2.0 \pm 0.5(\mathrm{stat.}) \pm 0.7(\mathrm{syst.}) \pm 0.08(\mathrm{lumi.})\,\mathrm{pb}$ **43.2%**

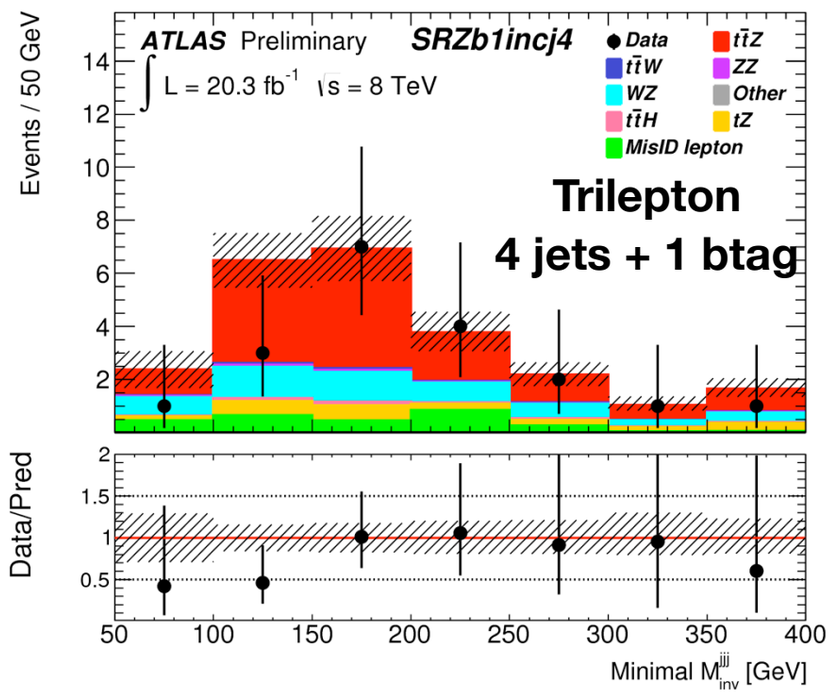
Top Couplings to Bosons $t\bar{t}V\,(V = \gamma, Z, W, H)$

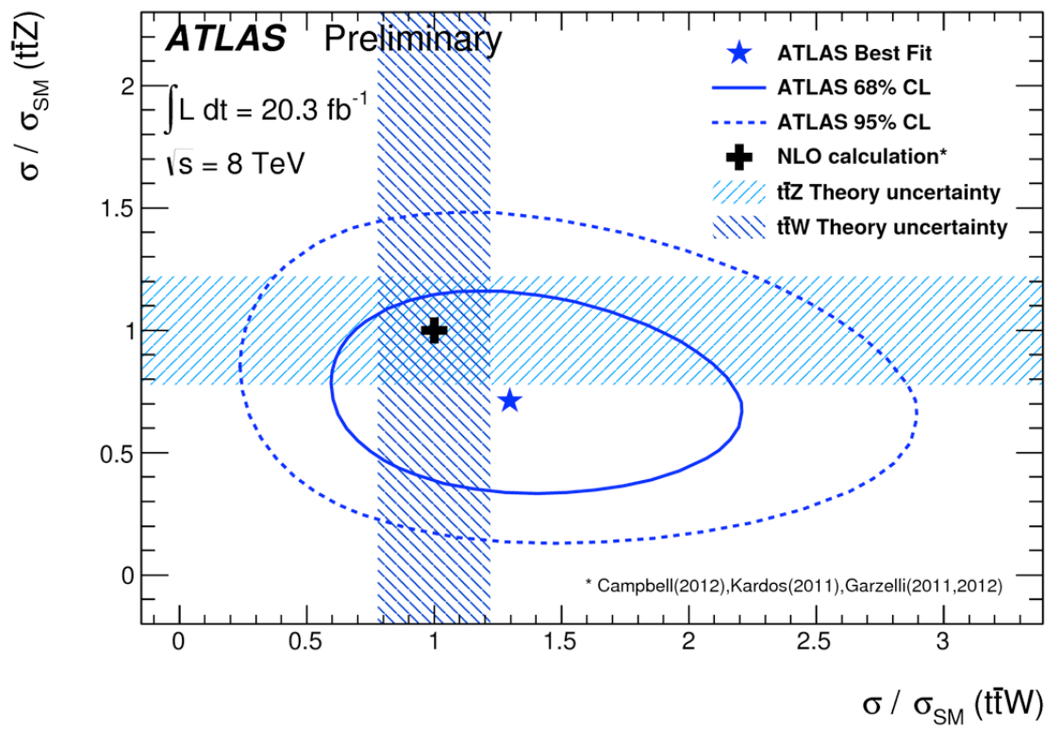
$t\bar{t}V\,, V = Z, W$

ATLAS-CONF-2014-038

- $t\bar{t}V$ **@ 8 TeV (20.3 fb^{-1}):**
  - Dilepton SS and OS & Trilepton Combined:

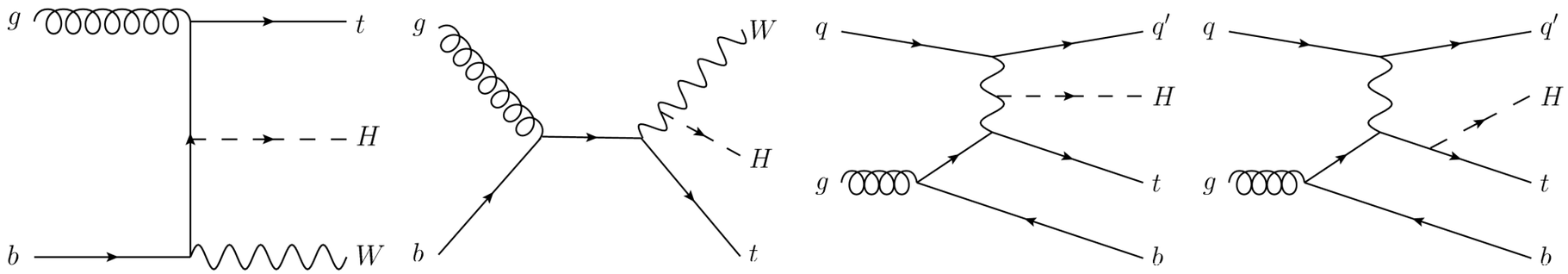
	Summary of combined simultaneous fit results		
Process	Measured cross-sections	Observed σ	Expected σ
18.7% $t\bar{t}Z$	$150^{+58}_{-54}(\text{total}) = 150^{+55}_{-50}(\text{stat.}) \pm 21(\text{syst.})$ fb	3.1	3.7
83.3% $t\bar{t}W$	$300^{+140}_{-110}(\text{total}) = 300^{+120}_{-100}(\text{stat.})^{+70}_{-40}(\text{syst.})$ fb	3.1	2.3



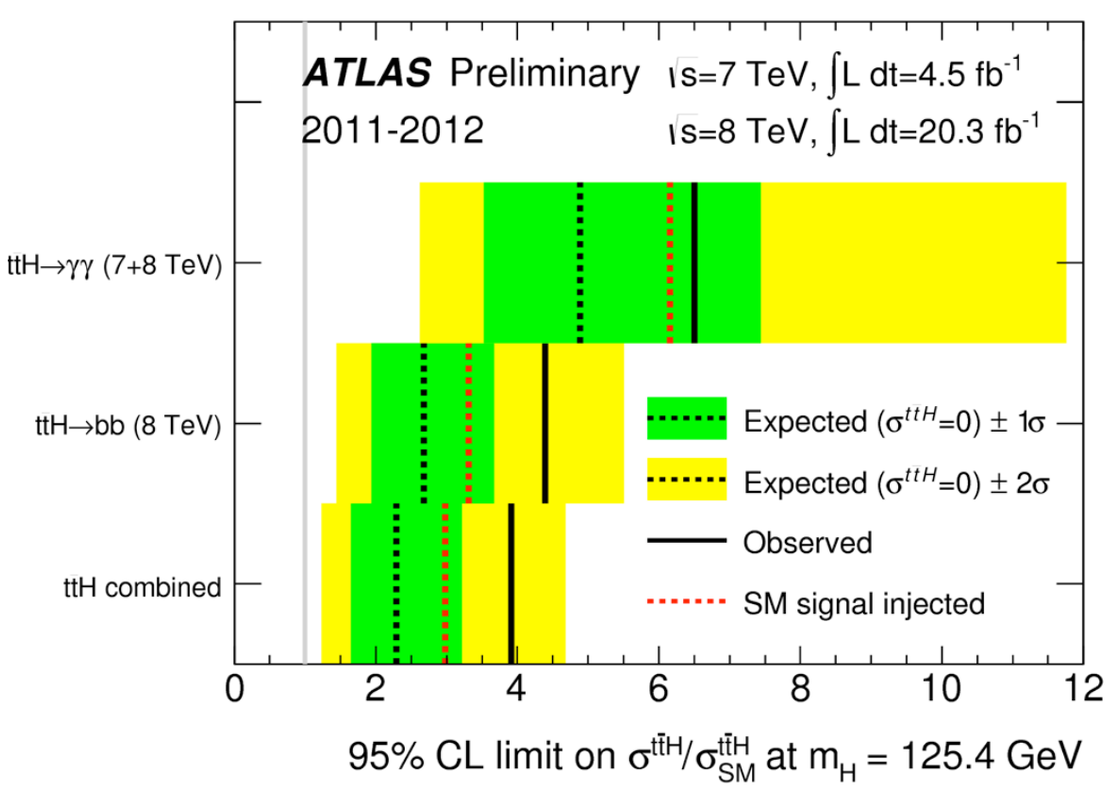


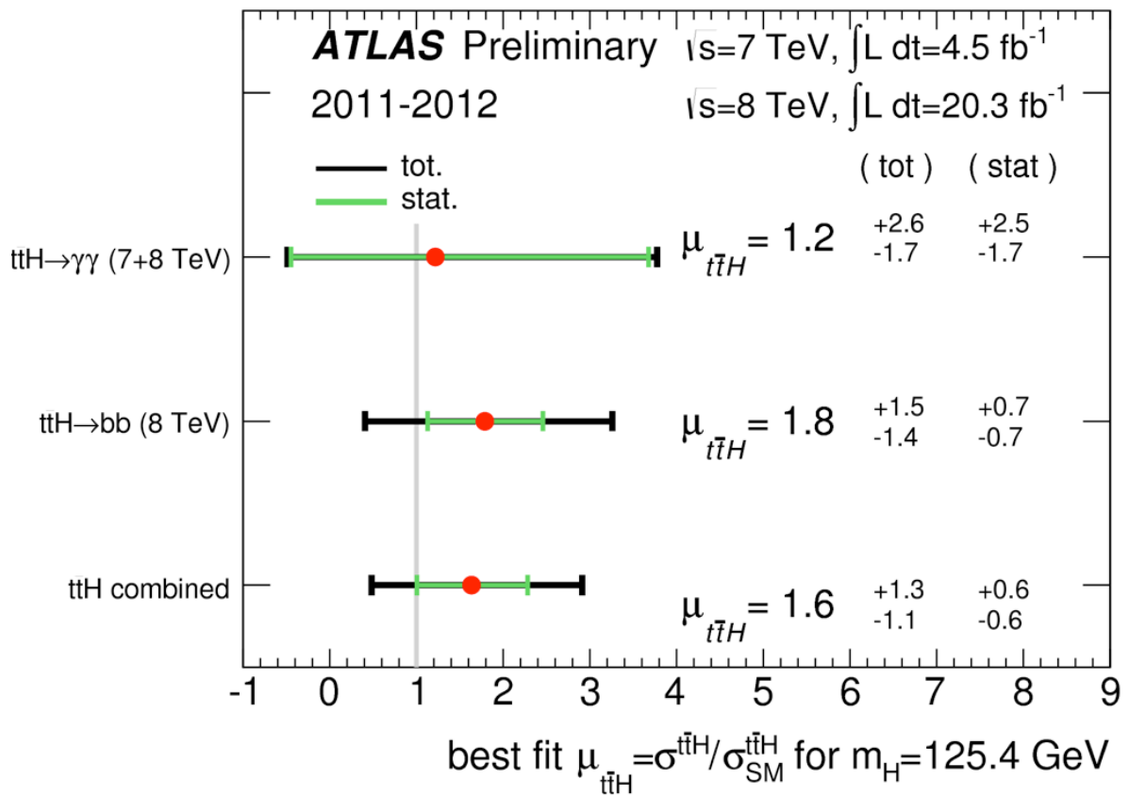
Top Couplings to Bosons $t\bar{t}V\,(V = \gamma, Z, W, H)$

$t\bar{t}H$



- $t\bar{t}H\ ,\ H \to b\bar{b}$ **@ 8 TeV (20.3 fb^{-1}):** ATLAS-CONF-2014-011
- $t\bar{t}H\ ,\ H \to \gamma\gamma$ **Combination of 7 (4.5 fb^{-1}) and 8 TeV (20.3 fb^{-1}):** ATLAS-CONF-2014-043
- **Combined Result** $t\bar{t}H\ ,\ H \to \gamma\gamma, b\bar{b}$ **:**





Conclusions

- Top quark studies with the ATLAS detector well under way
  ⇒ now addressing Precision Top Quark Measurements!

- Although no new physics seen in top quark physics, it is amazing how well things are going:
  - High Precision levels ⇒ Data used to constrain tt modelling (including PDFs)
  - Many measurements are already dominated by systematic errors;
  - Differential measurements will push the boundary that we can reach with statistics;

- Still a long way to go:
  - stay tuned for the final set of Run 1 top analyses!

- **There is a rich phenomenology in top quark physics which needs high precision tests @ATLAS and in the future ahead!**

POPH
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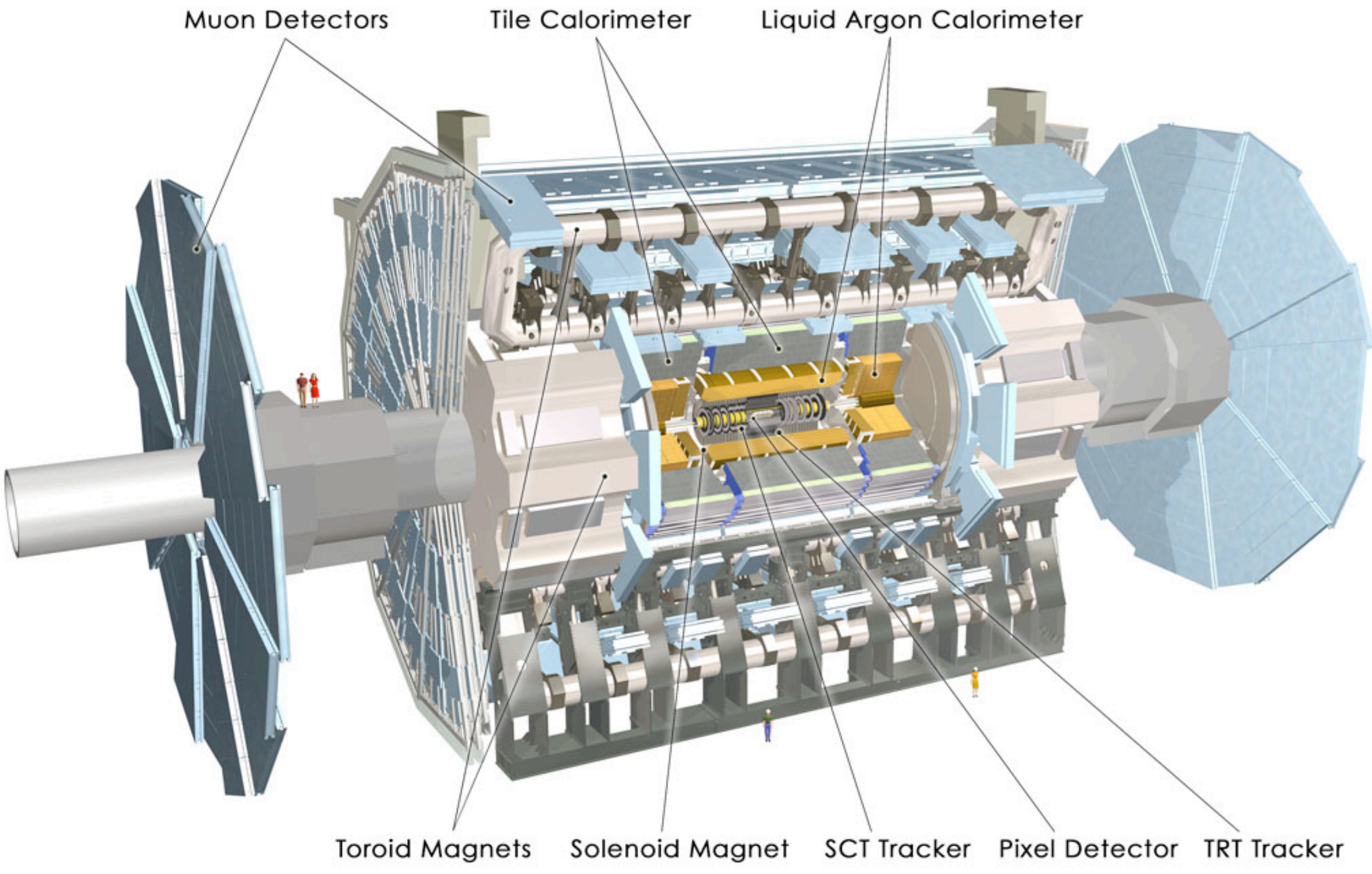
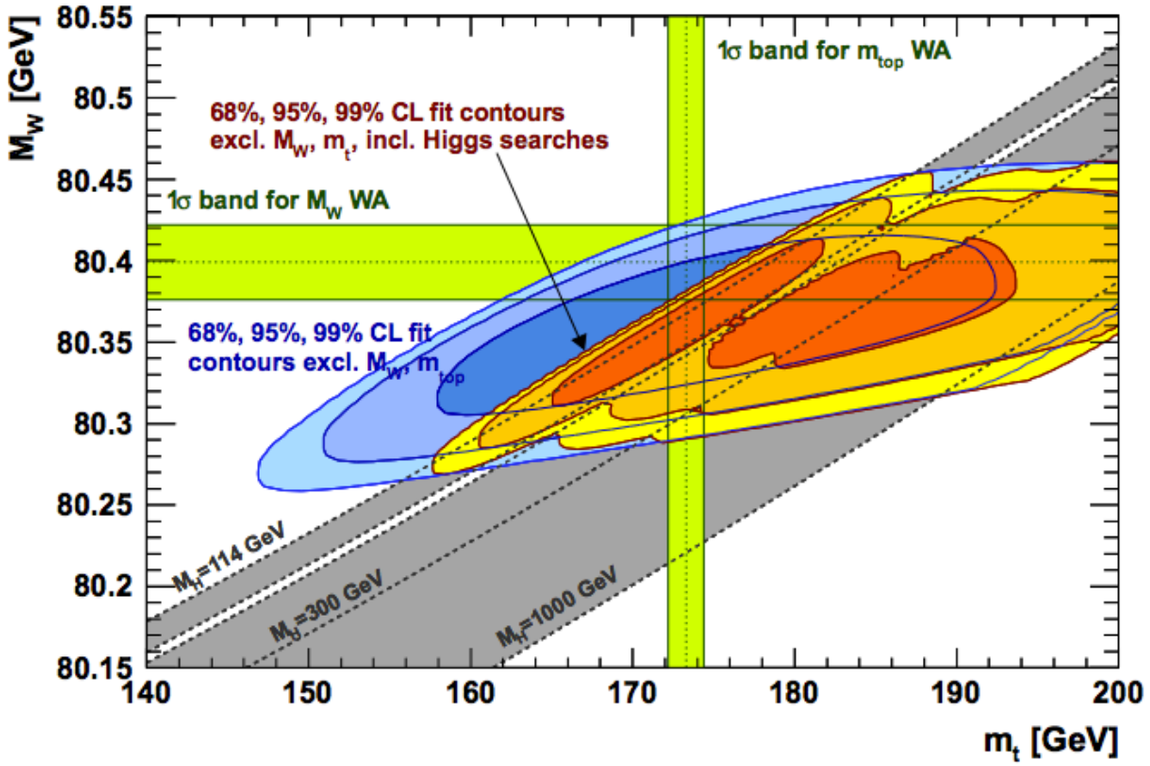
BACKUP SLIDES

The ATLAS Detector



Why the Top Quark ?

- **Heaviest of All Fundamental Particles in the Standard Model**:
  - Largest Mass ➙ Largest Coupling to SM Higgs
  - m_{Top} must be a fundamental parameter in the SM!



- Allows for Self-Consistency Checks of SM Post Higgs Discovery
- Top Quark Mass ~ EW Symmetry Breaking Scale

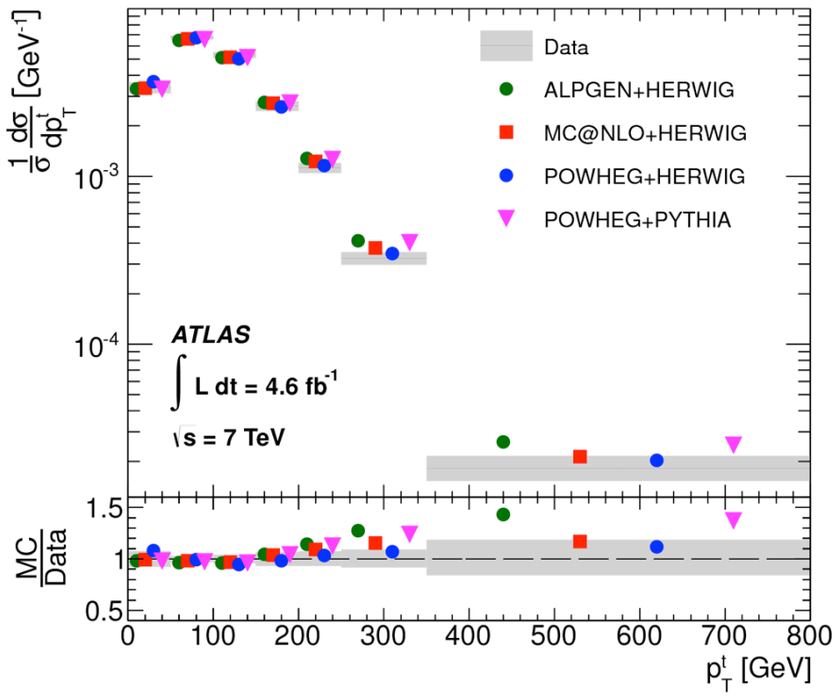
Cross-Section Measurements
Top Quark Pair Production ($t\bar{t}$)

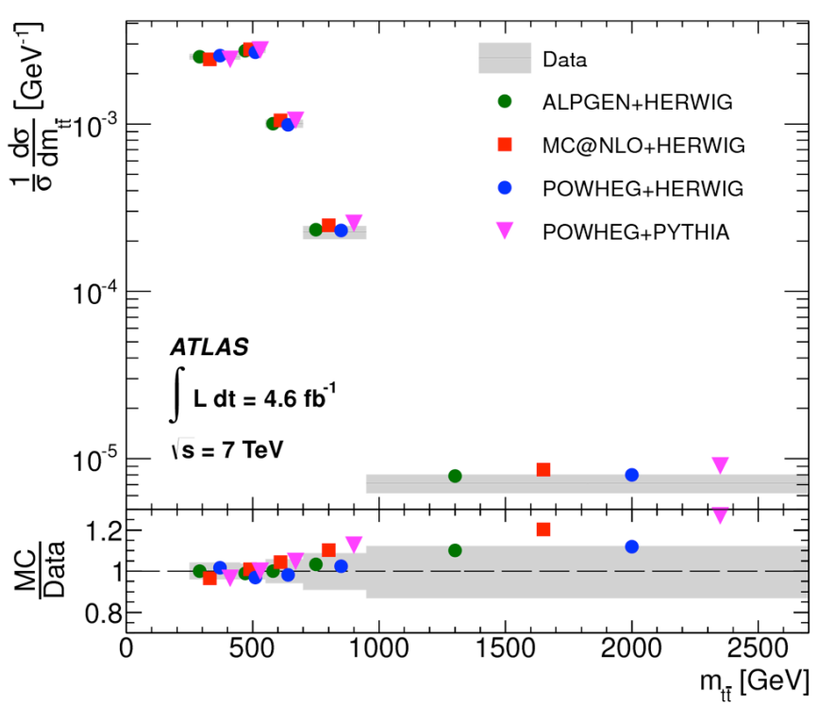
- **l+jets @ 8 TeV (5.8 fb^{-1})** $\sigma_{t\bar{t}} = 241 \pm 2(\text{stat.}) \pm 31(\text{syst.}) \pm 9(\text{lumi})\,\text{pb}$ **13.4%**

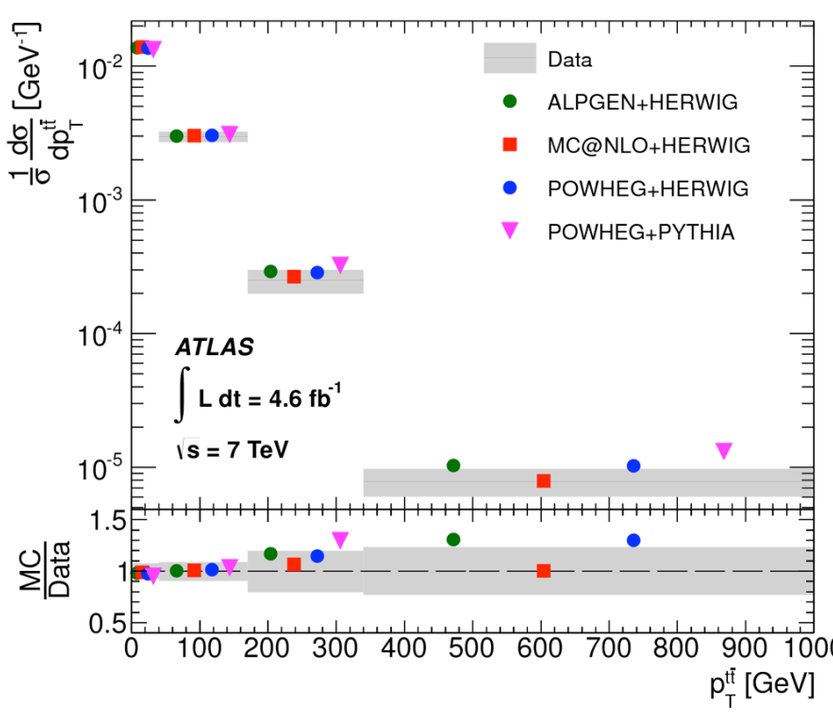
  ATLAS-CONF-2012-149

- **Differential $\sigma_{t\bar{t}}$ l+jets @ 7 TeV**

  arXiv 1407.0371 [hep-ex]

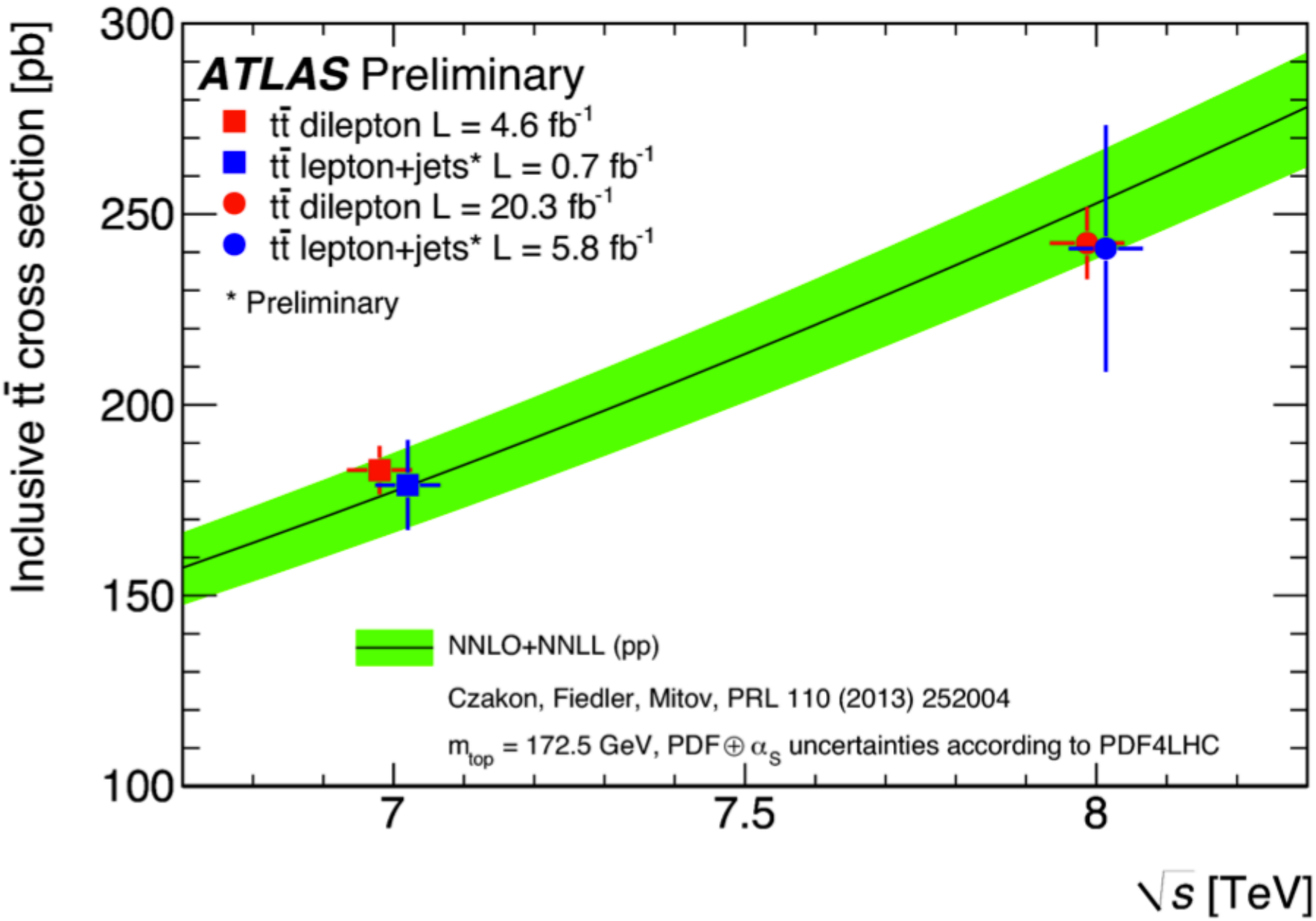






Cross-Section Measurements

Top Quark Pair Production ($t\bar{t}$)

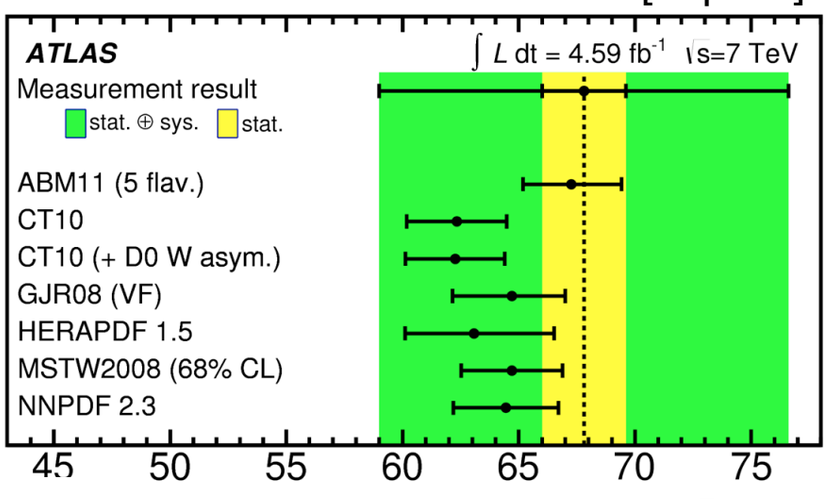


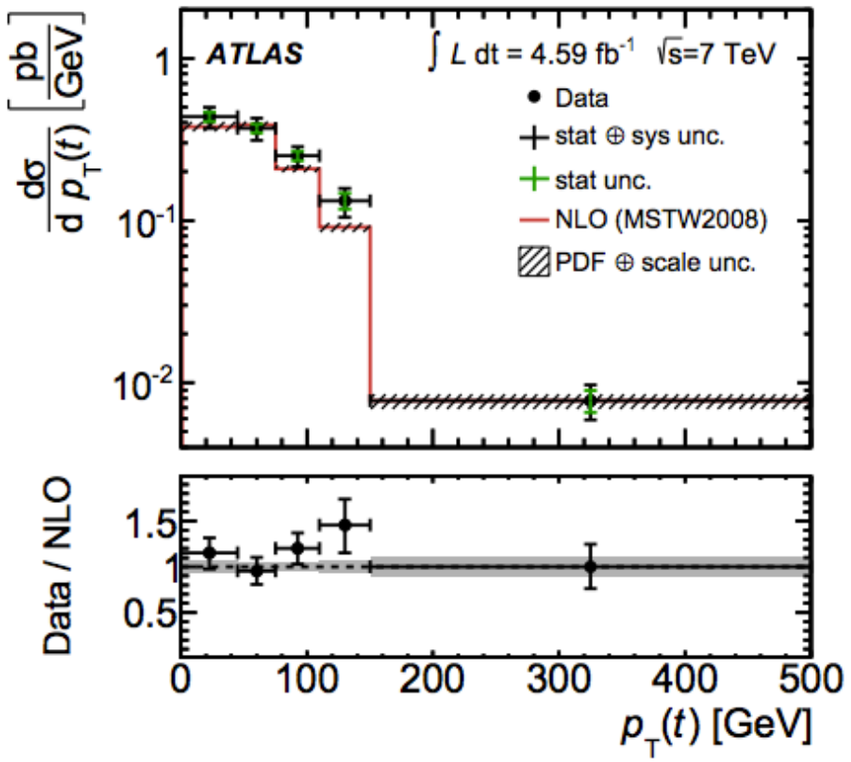
Cross-Section Measurements
Single Top Quark Production: t-channel

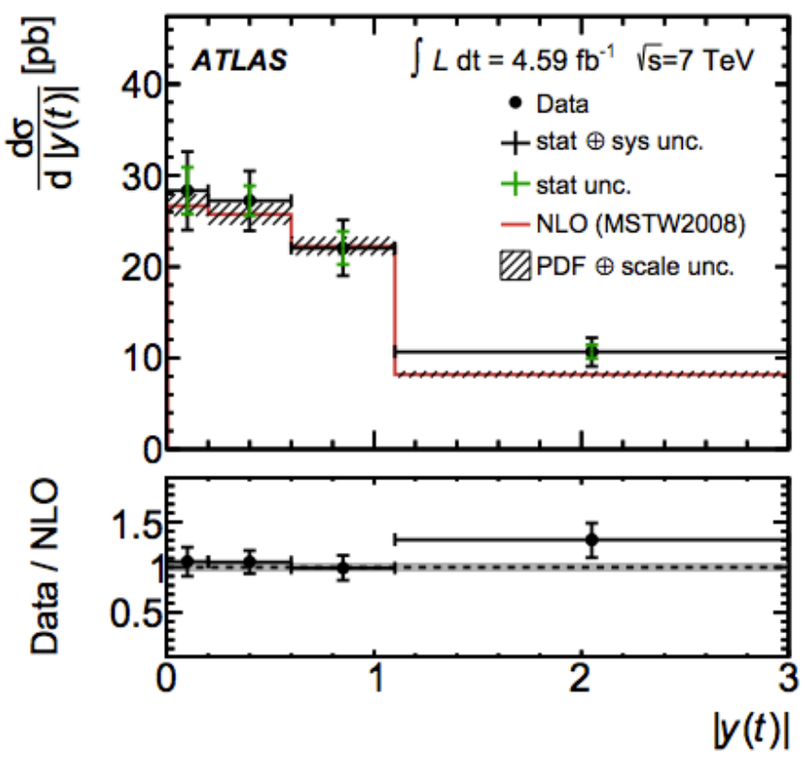
arXiv 1406.7844 [hep-ex]

- **Differential Cross Section:** NEW

Normalized differential cross sections measured as a function of transverse momentum and absolute rapidity







Top Couplings to Bosons $t\bar{t}V\,(V=\gamma,Z,W,H)$

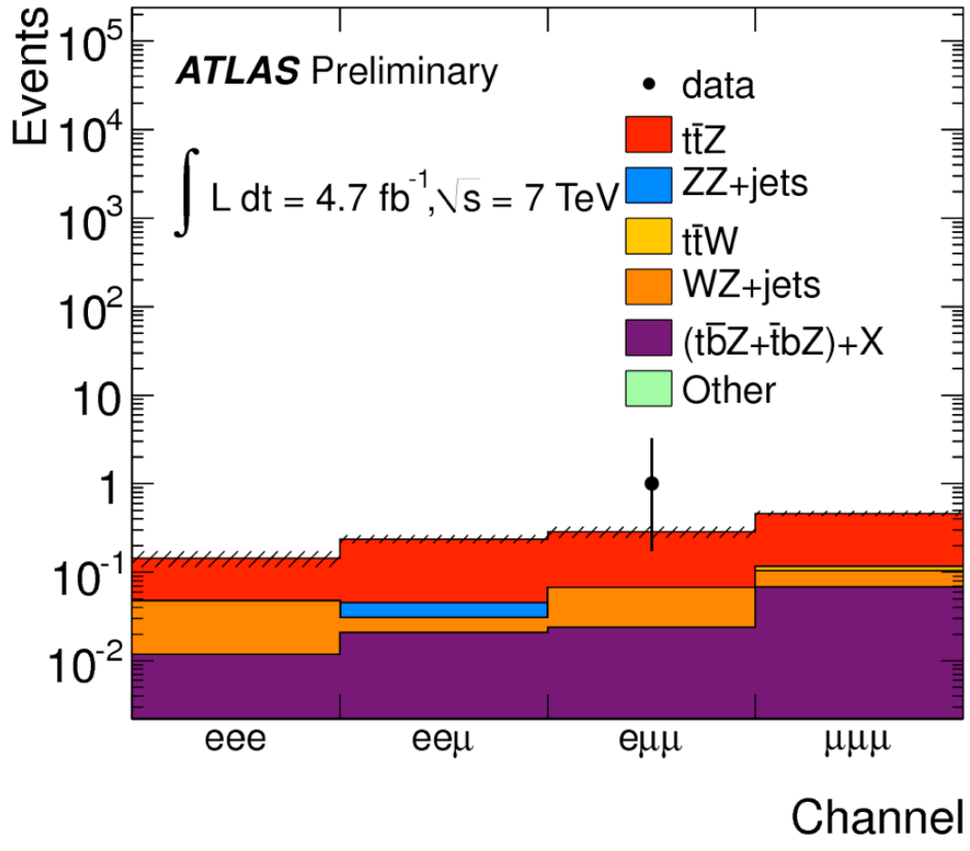
$t\bar{t}V\,,\,V=Z,W$

ATLAS-CONF-2012-126

- $t\bar{t}Z$ **@ 7 TeV (4.7 fb^{-1}):**
  - Trilepton Analysis: tt Lepton+jets topology ⊕ Z→l$^+$l$^-$ (≥1 b-jet)
  - ≥1 l$^+$l$^-$ (OSSF) pair with

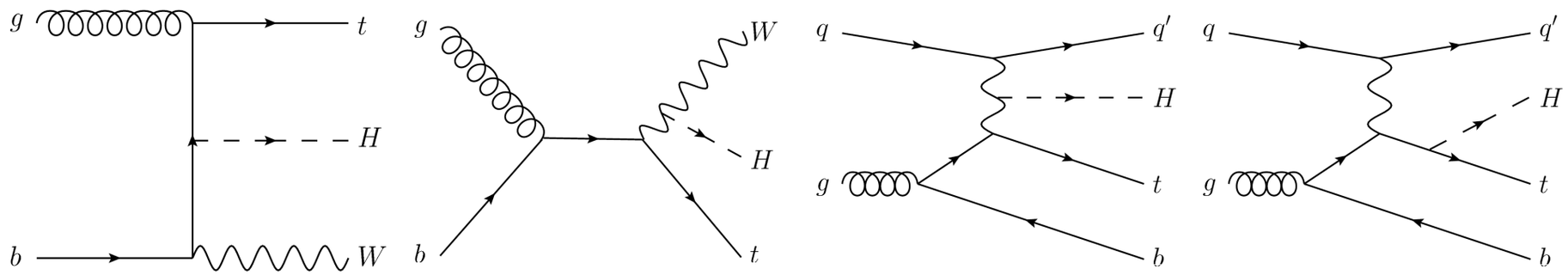
$$\sigma_{t\bar{t}Z} < 0.71\,\mathrm{pb}\,@95\%\,\mathrm{CL}$$

$$\sigma^{NLO,SM}_{t\bar{t}Z}(7TeV) = 0.14\,\mathrm{pb}$$



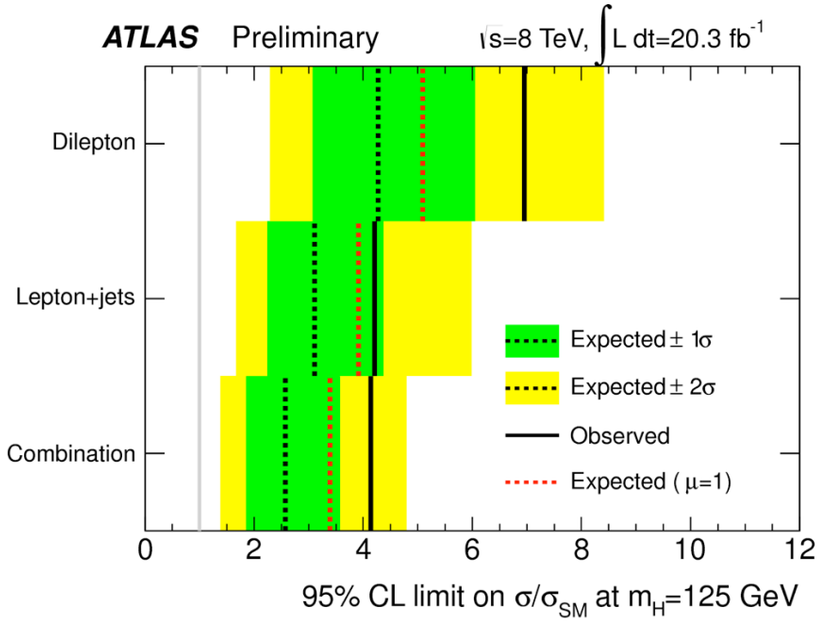
Top Couplings to Bosons $t\bar{t}V\,(V = \gamma, Z, W, H)$

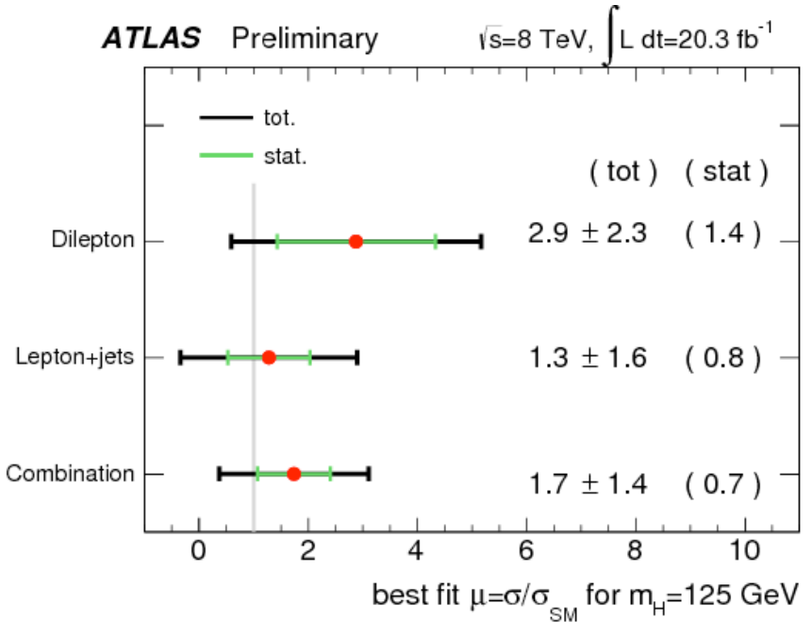
$t\bar{t}H$



- $t\bar{t}H\ ,\ H \to b\bar{b}$ **@ 8 TeV (20.3 fb^{-1}):** ATLAS-CONF-2014-011

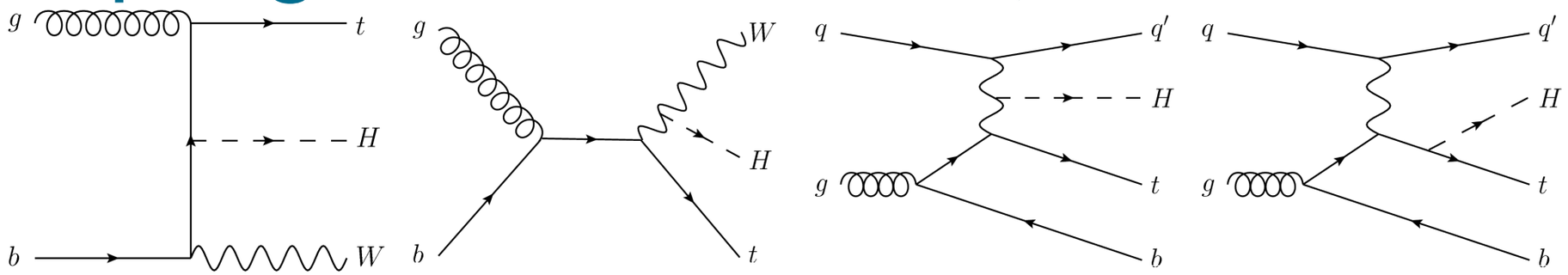
95% CL upper limit on σ/σ_{SM}	observed	-2 σ	-1 σ	median	+1 σ	+2 σ	median ($\mu = 1$)
Single Lepton	4.2	1.7	2.2	3.1	4.4	6.0	3.9
Dilepton	7.0	2.3	3.1	4.3	6.1	8.4	5.1
Combination	4.1	1.4	1.9	2.6	3.6	5.0	3.4





Top Couplings to Bosons $t\bar{t}V\,(V = \gamma, Z, W, H)$

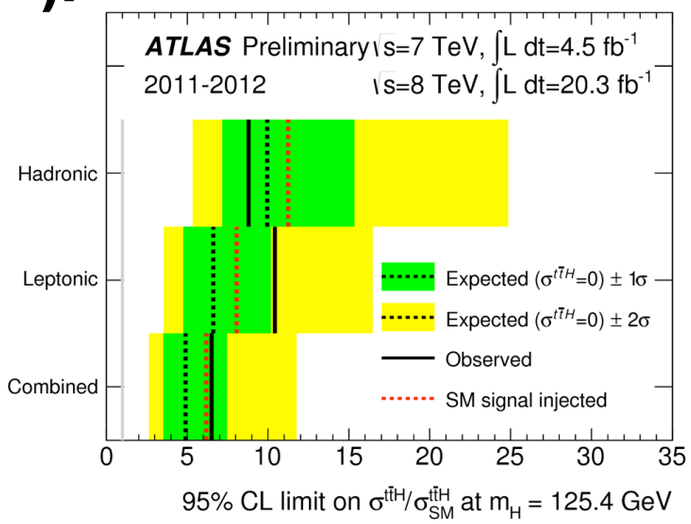
$t\bar{t}H$



- $t\bar{t}H\ ,\ H \to \gamma\gamma$ **Combination of 7 (4.5 fb^{-1}) and 8 TeV (20.3 fb^{-1}):** ATLAS-CONF-2014-043

Leptonic and hadronic Top quark decays;

	Observed limit	Expected limit	$+2\sigma$	$+1\sigma$	-1σ	-2σ
Combined (with systematics)	6.5	4.9	11.8	7.5	3.5	2.6
Combined (statistics only)	6.2	4.7	10.5	7.0	3.4	2.5
Leptonic (with systematics)	10.4	6.6	16.5	10.2	4.8	3.5
Leptonic (statistics only)	10.0	6.4	15.1	9.7	4.6	3.4
Hadronic (with systematics)	8.8	9.9	24.8	15.3	7.2	5.3
Hadronic (statistics only)	8.3	9.3	21.0	13.9	6.7	5.0



- **Combined Result**

$t\bar{t}H\ ,\ H \to \gamma\gamma, b\bar{b}$