

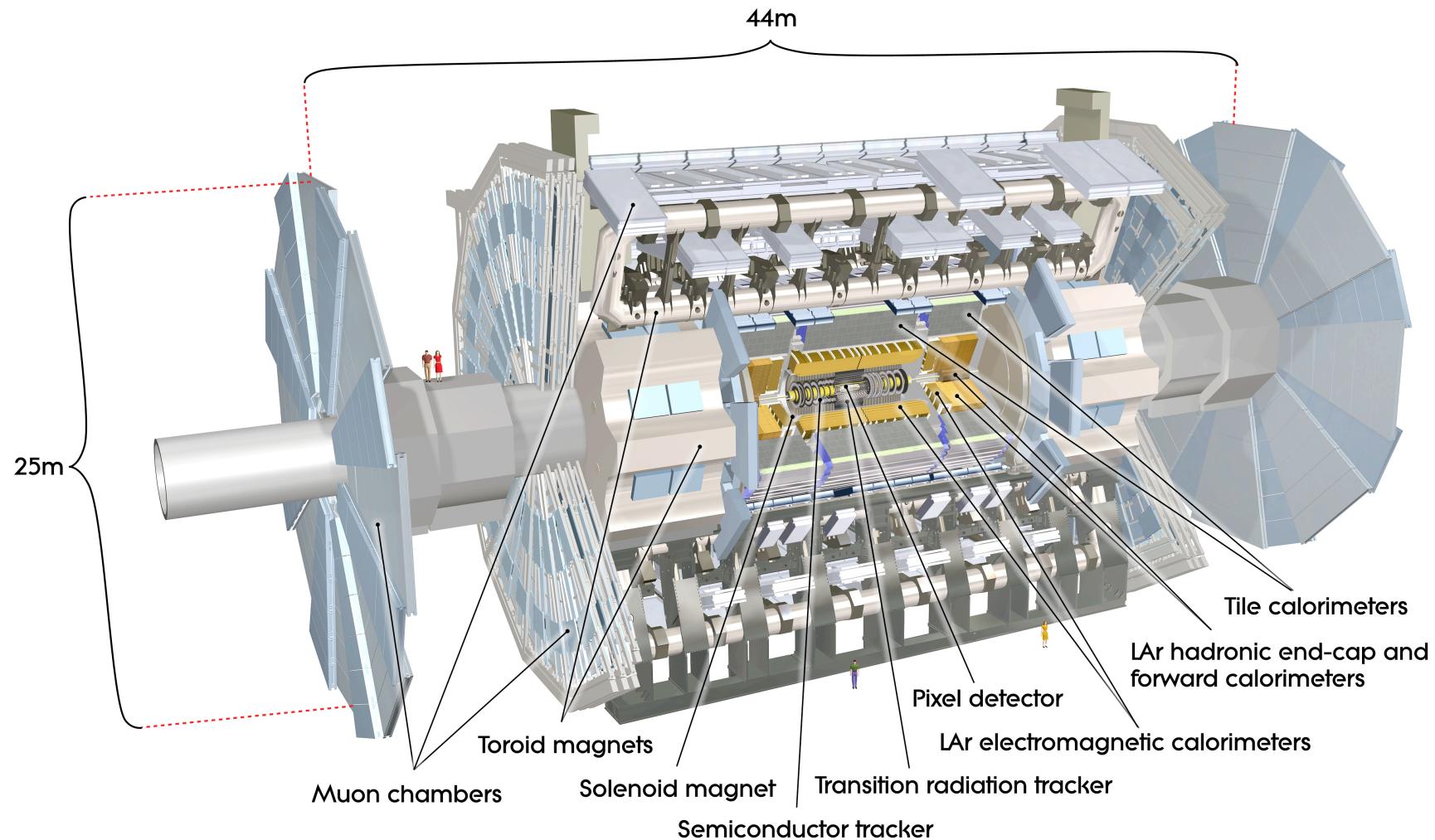


Selected Top Results from ATLAS LoopFest 2012

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The Atlas Detector





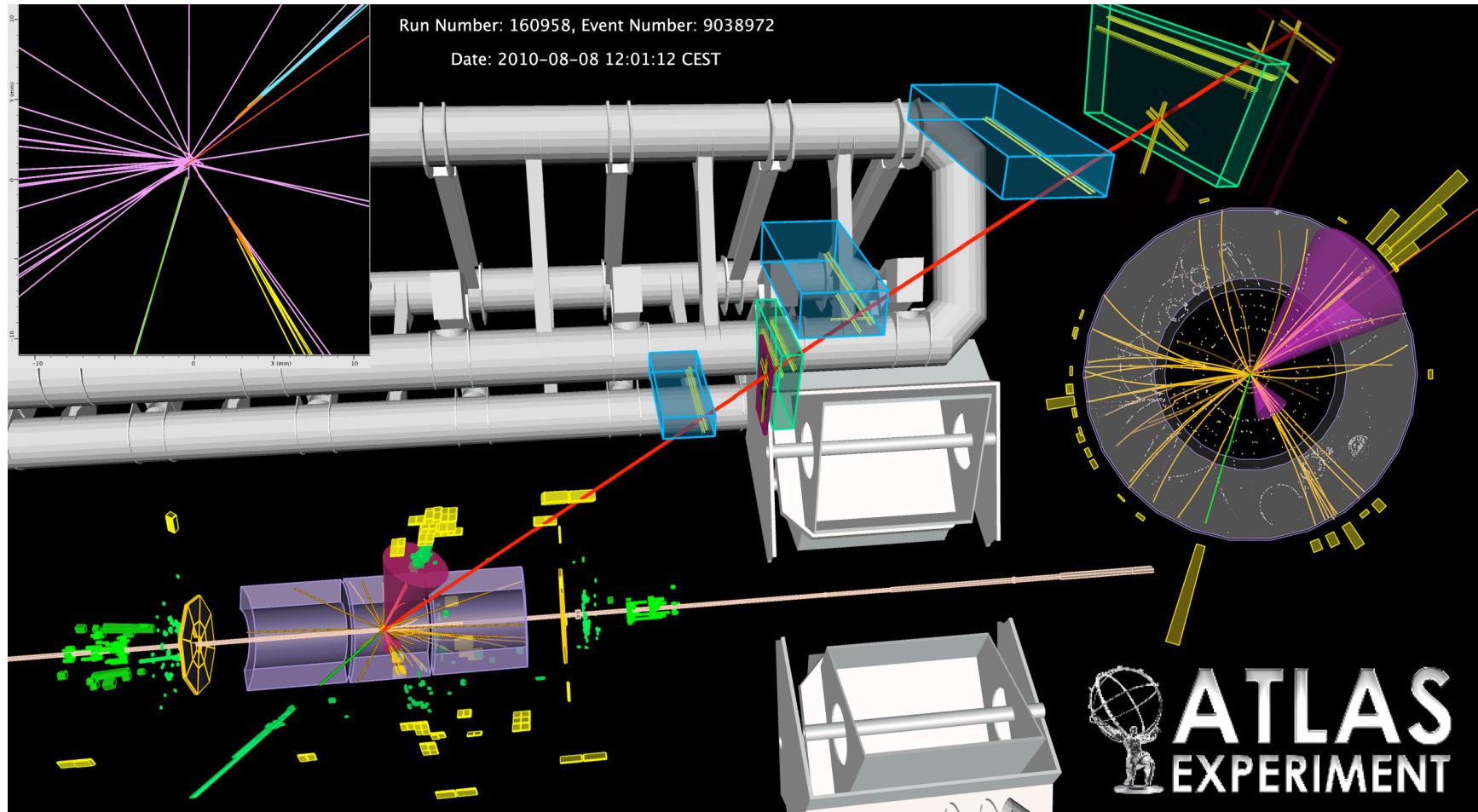
Top quark signature

$t \rightarrow Wb$, $W \rightarrow \ell\nu$ or $W \rightarrow \text{jet jet}$

- **Electrons:** Calorimeter and tracking information.
 - Isolated , high p_T
- **Muons:** Muon Chamber tracks matched to inner detector track.
 - Isolated, high p_T
- **Neutrinos:** indicated by $E_t^{\text{miss}} = -\sum p_T$ of detected objects
- **Jets:** Anti- k_T algorithm, $R=0.4$
 - High pT
- **b-jets:** identified using secondary vertex and/or track impact parameters.



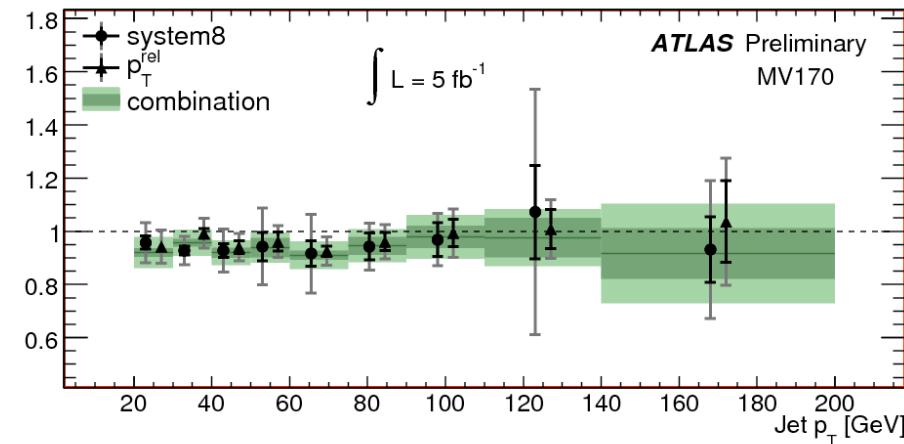
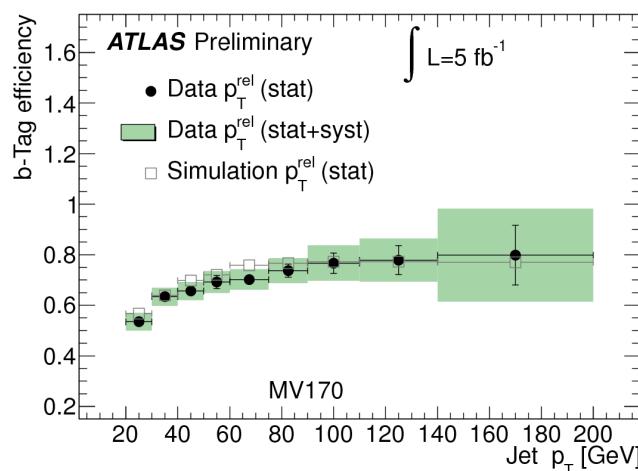
$t\bar{t} \rightarrow e\nu + \mu\nu + \text{jets}$





b-jet tagging Calibration

- One example of using data to calibrate results.
 - Use $b \rightarrow \mu X$ to enhance b-jet purity, and measure tagging efficiency.
 - Determine scale factor to correct eff. Determined from MC.



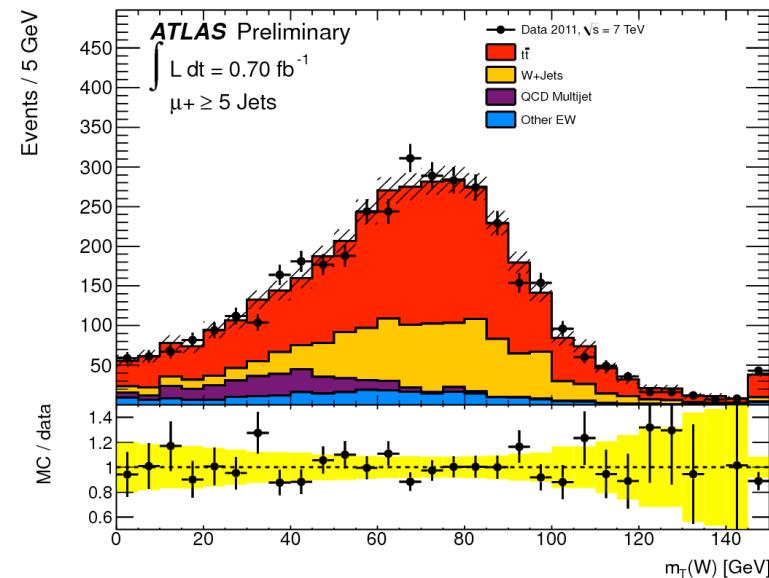
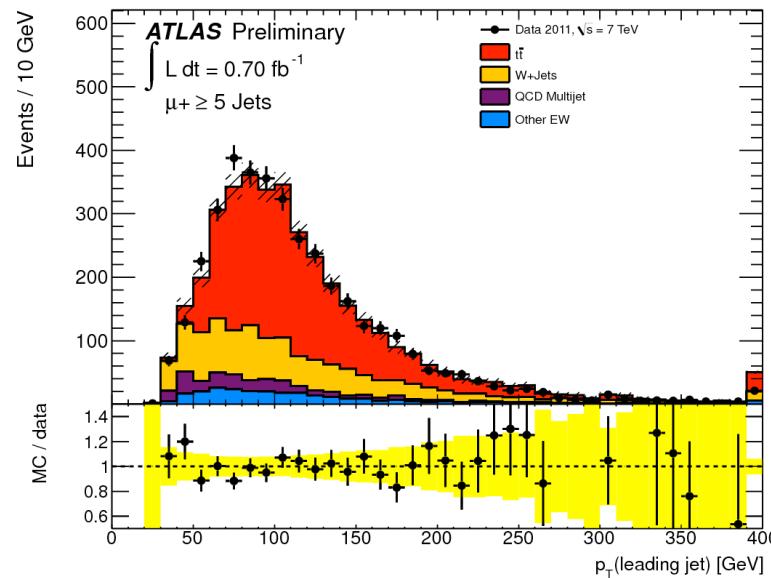


$t\bar{t}$ cross section in lepton+jets



ATLAS-CONF-2011-121 $\int \mathcal{L} = 0.70 \text{ fb}^{-1}$

- Uses e/ μ final states (plus jets)
- likelihood discriminant using kinematic differences between signal and background.
 - Lepton η , leading jet p_T , aplanarity, $H_{t,3p} = \frac{\sum_{i=3}^{N_{jets}} |p_{T,i}^2|}{\sum_{j=1}^{N_{objects}} |p_{z,j}|}$
- Simultaneous fit for Signal and Background



$$\sigma_{tt} = 179.0 \pm 3.9(\text{stat}) \pm 9.0(\text{syst}) \pm 6.6(\text{lumi}) \text{ pb}$$

Largest syst. is differences between MC generators

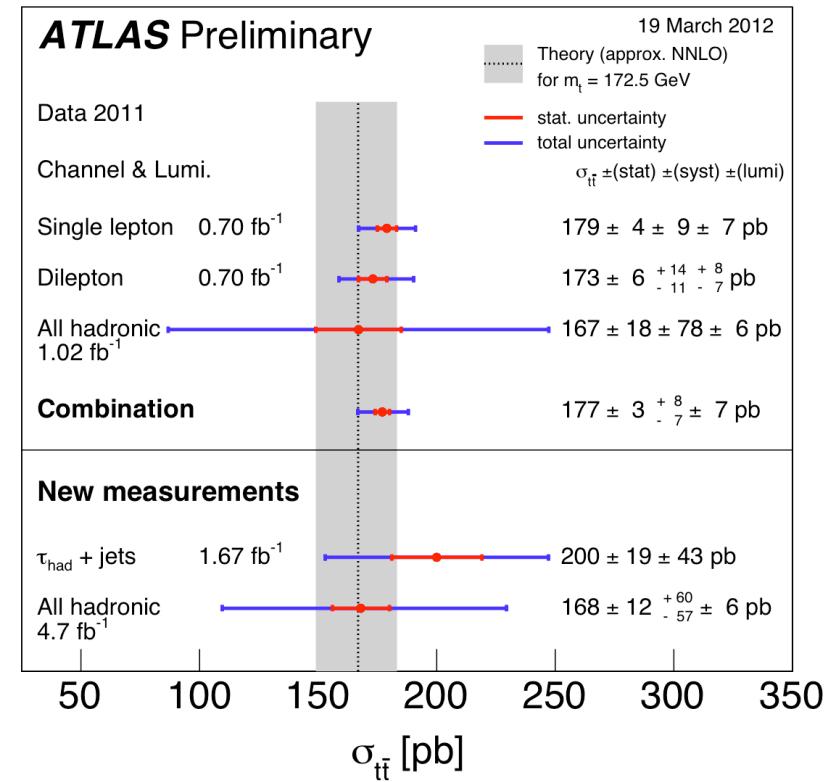
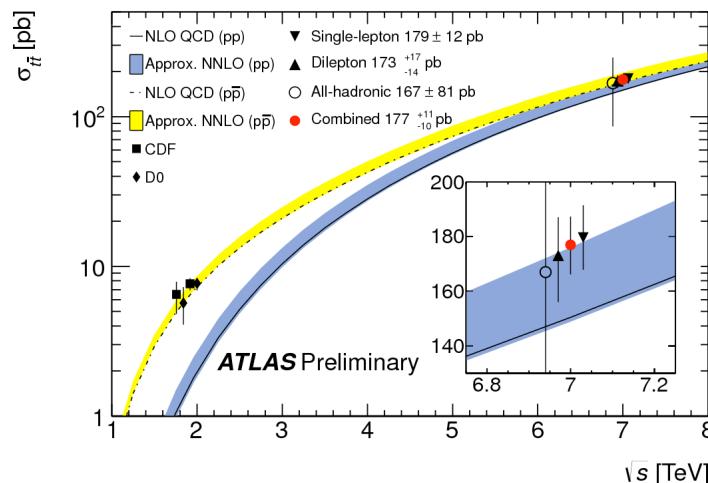


Summary of cross-section measurements



All ATLAS measurements of $\sigma_{t\bar{t}}$ are consistent with each other.

NNLO prediction of $\sigma_{t\bar{t}}$ is consistent with measurement, albeit with larger uncertainty.



NEW: $e/\mu + \tau$ jets arXiv:1205.2067 $fL = 2.05 \text{ fb}^{-1}$

$\sigma_{t\bar{t}} = 186.0 \pm 13(\text{stat}) \pm 20(\text{syst}) \pm 7(\text{lumi}) \text{ pb}$

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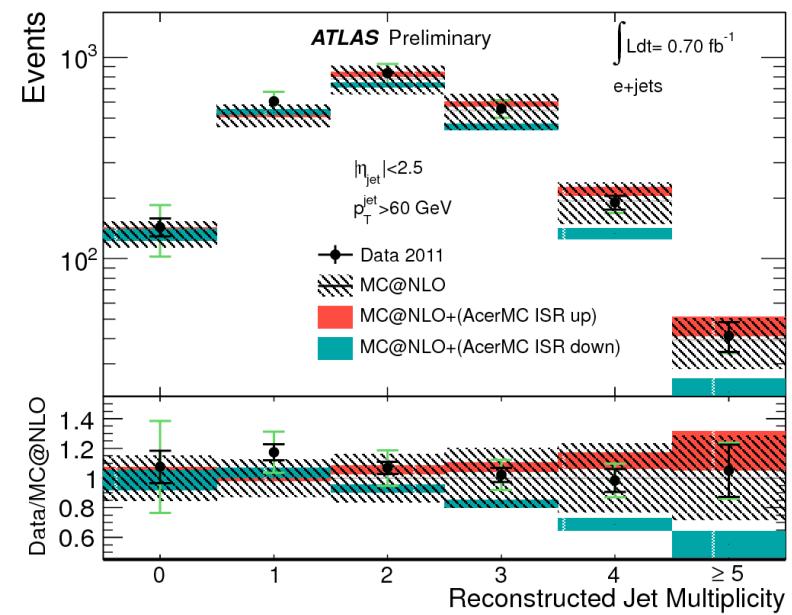
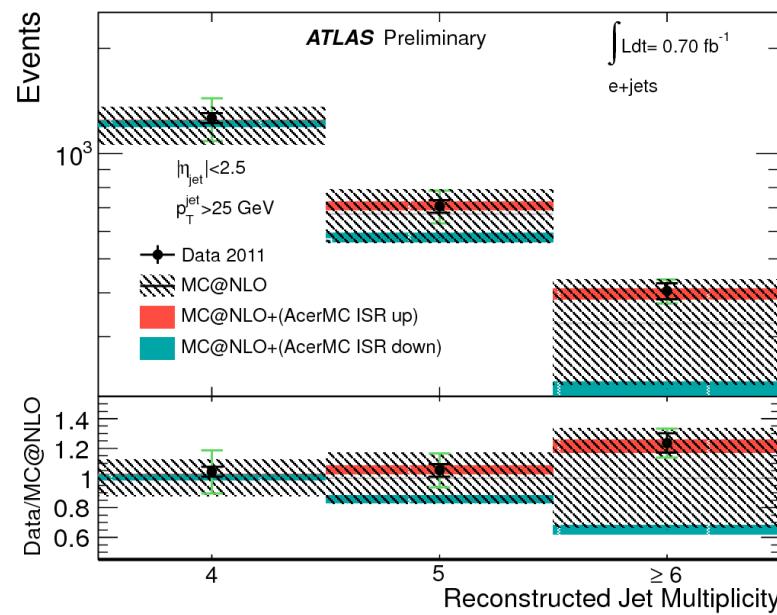
Loop Fest 2012



$t\bar{t} + \text{jet}$

ATLAS-CONF-2011-142 $\int \mathcal{L} = 0.70 \text{ fb}^{-1}$

- lepton (e, μ) + ≥ 4 jets ($p_T > 25 \text{ GeV}$)
- Background subtracted N_{jet} distribution, with jet p_T cut



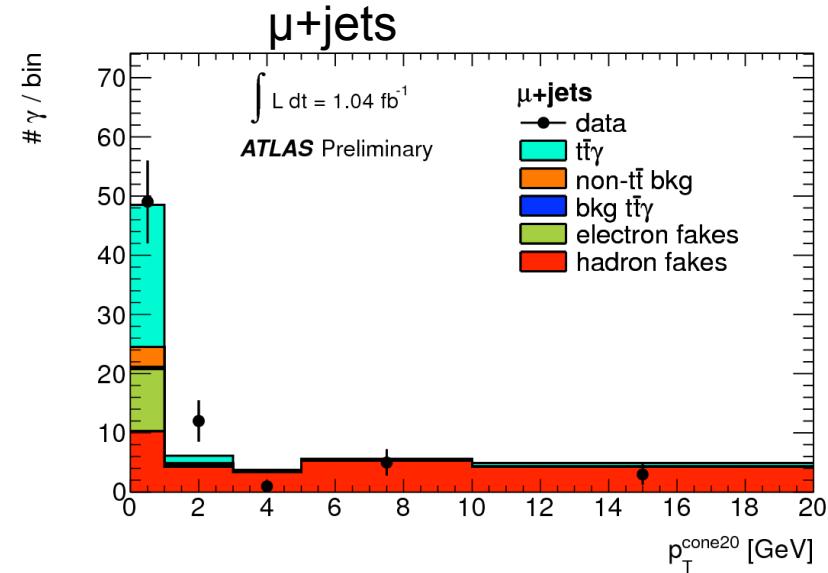
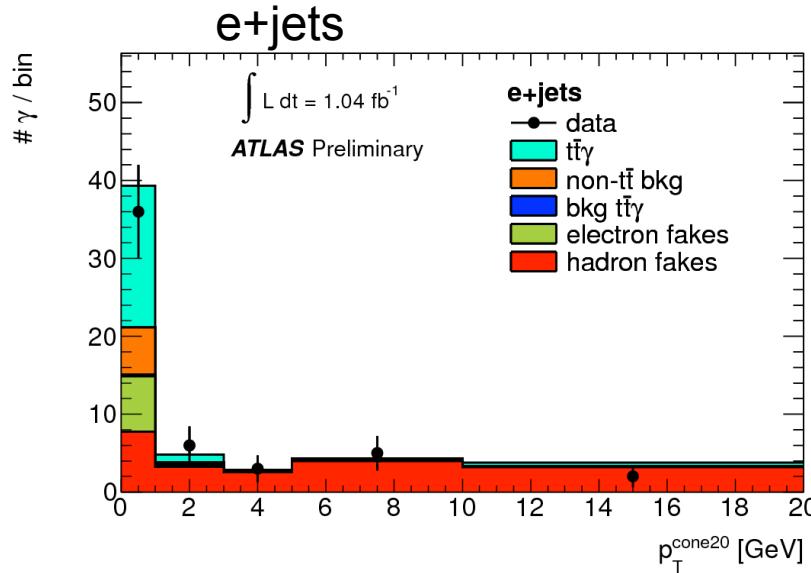
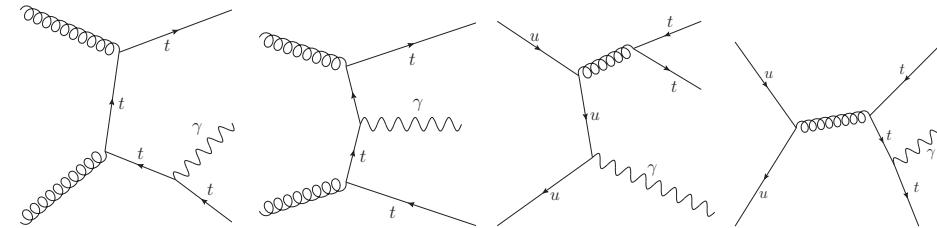


$t\bar{t} + \gamma$



ATLAS-CONF-2011-153 $\int \mathcal{L} = 1.04 \text{ fb}^{-1}$

- Probe top QED coupling
- lepton (e, μ) + ≥ 4 jets
- $p_T(\gamma) > 15 \text{ GeV}$
 - Generator $> 8 \text{ GeV}$
- Fit S and B templates for $p_T^{\text{cone}20}$ in $e+\text{jets}$ and $\mu+\text{jets}$ simultaneously.
 - $p_T^{\text{cone}20} \equiv$ scalar sum of track pT with $\Delta R < 0.2$ around photon candidate



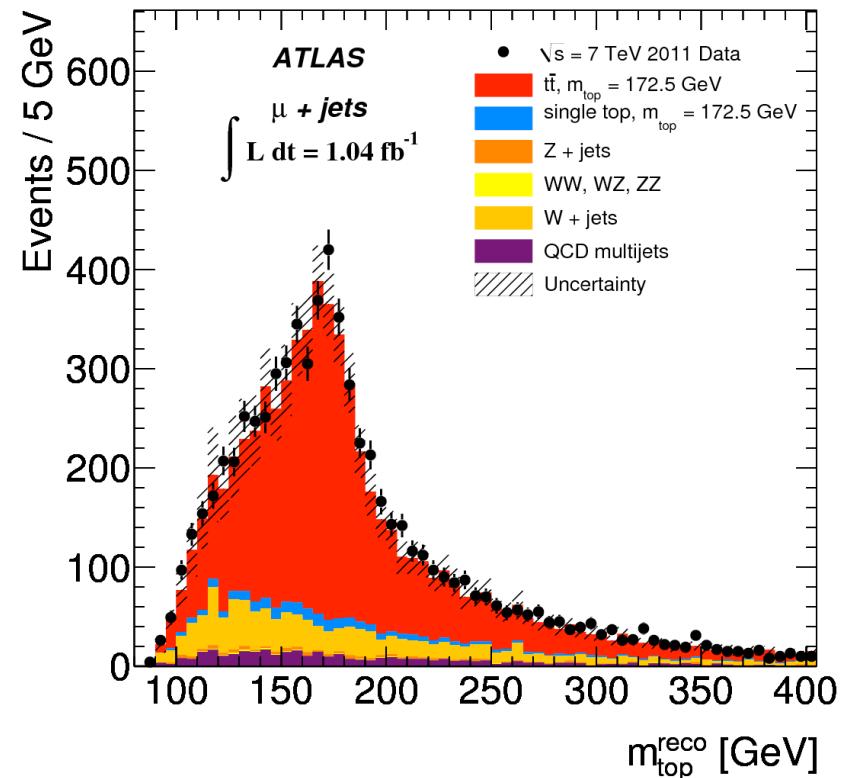
$$\sigma_{t\bar{t}\gamma} = 2.00 \pm 0.5(\text{stat}) \pm 0.7(\text{syst}) \pm 0.08(\text{lumi}) \text{ pb} \quad \text{SM } 2.1 \pm 0.4 \text{ pb}$$



Top Quark Mass

arXiv:1203.5755 $\int \mathcal{L} = 1.04 \text{ fb}^{-1}$

- $(e, \mu) + \text{jets}$
- At least one jet b-tagged
- Observables:
 - Jet-pair mass (m_W)
 - Jet-triplet mass (m_t)
- Two parameter fit
 - m_t
 - JSF \equiv Global Jet energy Scale Factor (p_T and η independent)



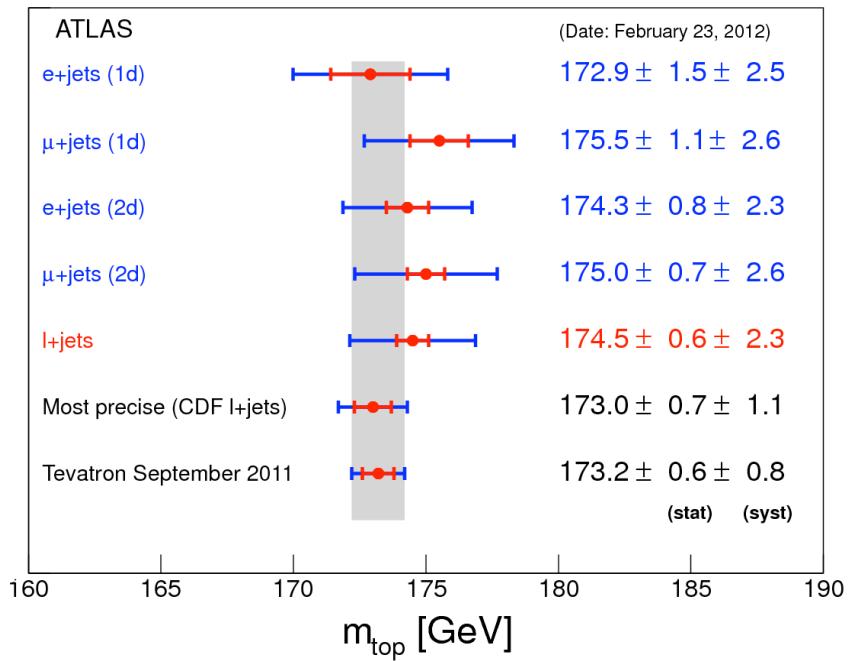
$$m_t = 174.5 \pm 0.6(\text{stat}) \pm 2.3(\text{syst}) \text{ GeV}$$



Top quark mass

Already systematics limited

- 3 main sources
 - Relative energy scale between b-jet and light jet
 - Modeling of ISR and FSR
 - Light quark jet energy scale



Will be challenging to reduce systematics to level of Tevatron.



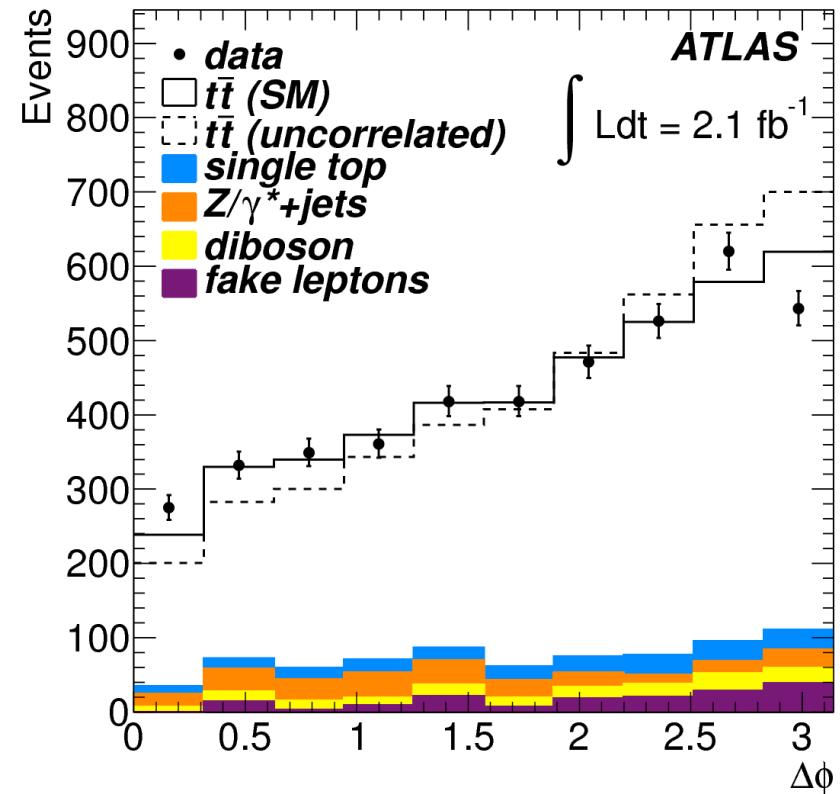
Spin Correlation in $t\bar{t}$ production

arXiv:1203.4081 $\int \mathcal{L} = 2.1 \text{ fb}^{-1}$

- Di-leptonic $t\bar{t}$ events (ee, $\mu\mu$, e μ)
- Sensitive observable: $\Delta\phi$ between leptons in lab frame.
- From fit, extract $f^{\text{SM}} \equiv$ fraction of standard model-like events.
- Can also determine asymmetry between aligned and anti-aligned t and \bar{t} spins.
 - $A_{\text{basis}} = A_{\text{basis}}^{\text{SM}} f^{\text{SM}}$

$$f^{\text{SM}} = 1.30 \pm 0.14^{+0.27}_{-0.22}$$

Inconsistent with zero spin correlation with significance of 5.1 sigma





Charge Asymmetry in $t\bar{t}$ production



arXiv:1203.4211 $\int \mathcal{L} = 1.04 \text{ fb}^{-1}$

Tevatron experiments report $2-3\sigma$ excess over SM expectations in A_{FB} .

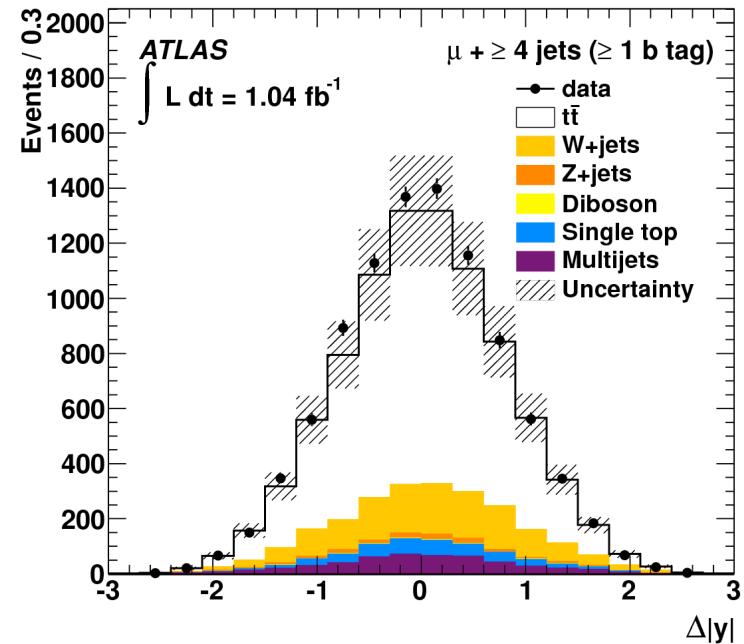
At LHC, $A_{FB}=0$, but BSM effects would be manifest in a charge asymmetry.

$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

where $\Delta|y| = |y_t| - |\bar{y}_t|$

SM value is $A_C = 0.006 \pm 0.002$ (MC@NLO)

- ATLAS uses $(e,\mu)+\text{jets}$.
- Lepton charge determines $t(\bar{t})$





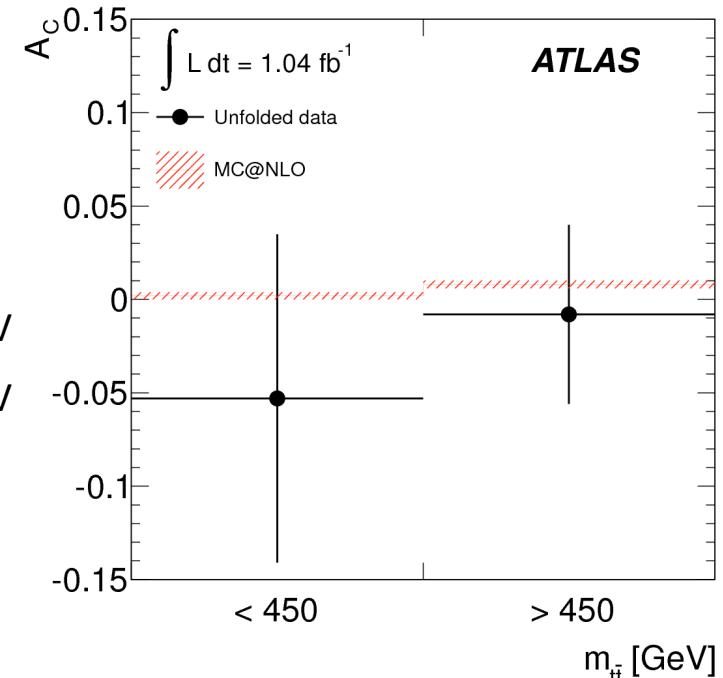
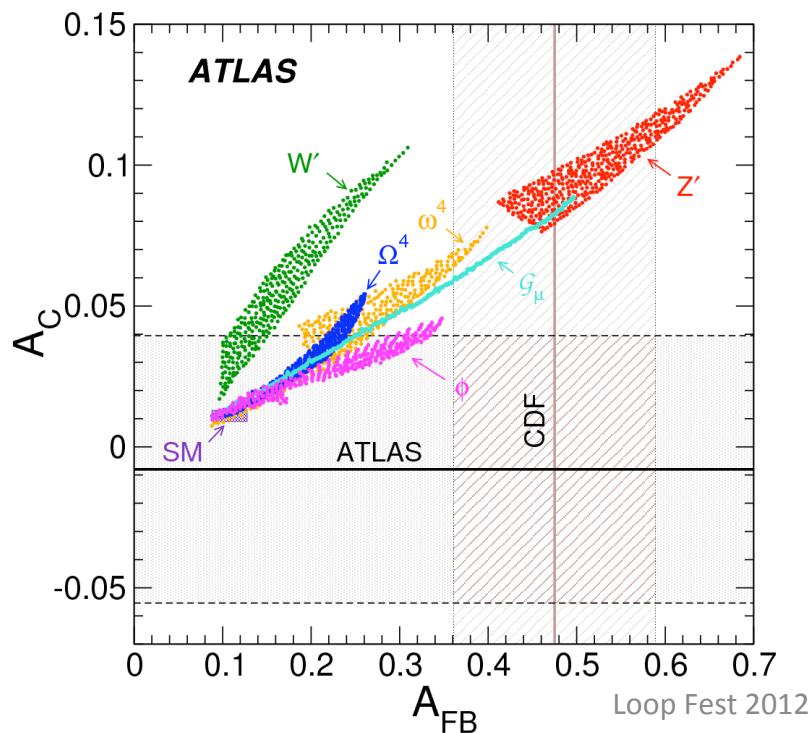
Constraining BSM with A_C

- Two inv. mass bins:
 - $m_{\bar{t}t} < 450 \text{ GeV}$
 - $m_{\bar{t}t} > 450 \text{ GeV}$

$$A_C = -0.018 \pm 0.028(\text{stat}) \pm 0.023(\text{syst})$$

$$-0.053 \pm 0.070(\text{stat}) \pm 0.054(\text{syst}) \quad m_{\bar{t}t} < 450 \text{ GeV}$$

$$-0.008 \pm 0.035(\text{stat}) \pm 0.032(\text{syst}) \quad m_{\bar{t}t} > 450 \text{ GeV}$$



Limits on allowed A_C and A_{FB} regions can constrain models proposed to explain the value of A_{FB} observed at Tevatron.



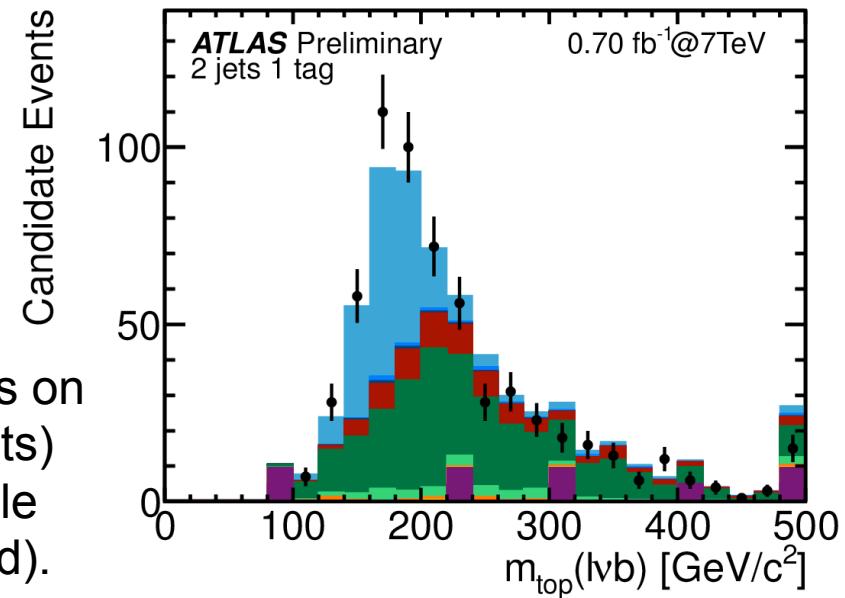
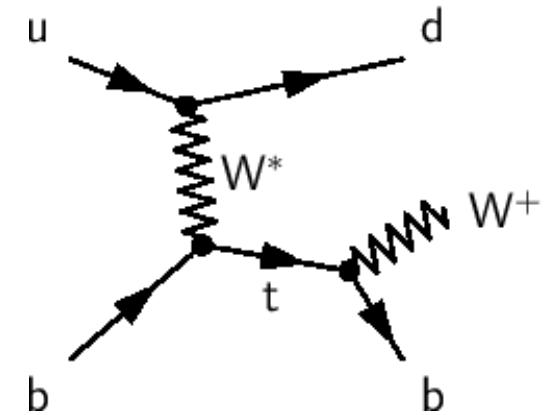
Single top cross section

ATLAS-CONF-2011-101 $\int \mathcal{L} = 0.70 \text{ fb}^{-1}$

- **t-channel W-exchange**
- Cut and neural network analysis
 - $\ell + E_t^{\text{miss}} + 2$ or 3 jets
 - b-tagging
 - Kinematic quantities

$$\sigma_t = 90 \pm 9(\text{stat})^{+31}_{-20}(\text{syst}) \text{ pb}$$

m_{top} after cuts on
 $\eta_{\text{jet}}, H_T, \Delta\eta(\text{jets})$
for 2jet sample
(one b-tagged).





Single top cross section

ATLAS-CONF-2011-104 $\int \mathcal{L} = 0.70 \text{ fb}^{-1}$

- Associated Wt production
- Cut-based analysis, both $W \rightarrow \ell \nu$

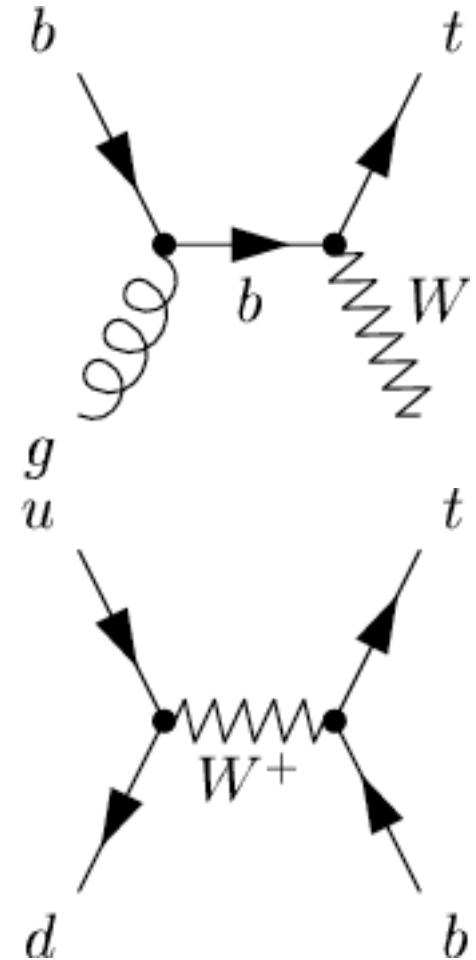
$$\sigma_t = 14^{+5.3}_{-5.1}(\text{stat})^{+9.7}_{-9.4}(\text{syst}) \text{ pb}$$

$$\sigma_t < 39.1(40.6) \text{ pb @95%CL}$$

- obs(exp)

ATLAS-CONF-2011-118 $\int \mathcal{L} = 0.70 \text{ fb}^{-1}$

- s-channel W
- Cut-based, $W \rightarrow \ell \nu$
- $\sigma_t < 26.5(20.5) \text{ pb @95%CL}$

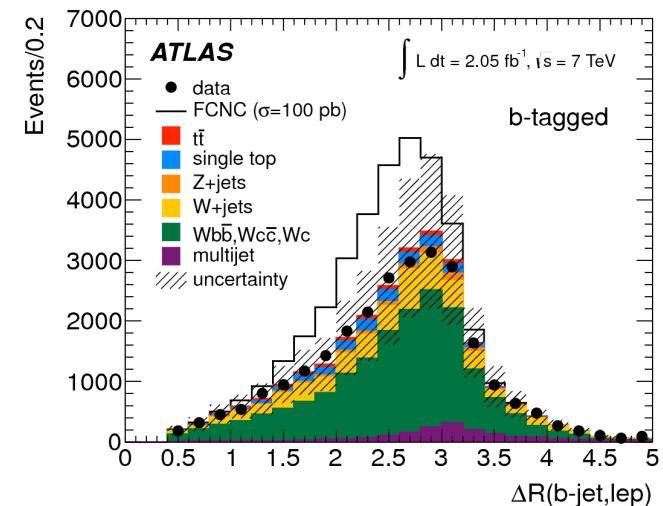
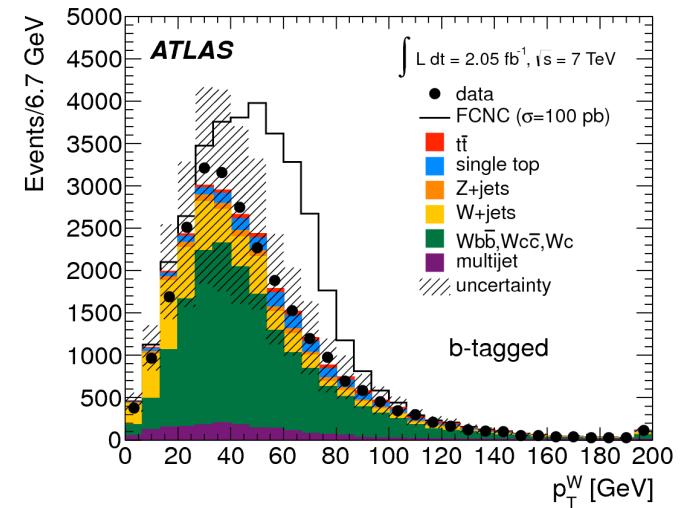




FCNC single top production

arXiv:1203.0529 $\int \mathcal{L} = 2.05 \text{ fb}^{-1}$

- $qg \rightarrow t \rightarrow Wb, W \rightarrow \ell\nu$
- Neural-net analysis
- Most significant variable:
 - $W p_T, \Delta P(\text{b-jet}, \ell), \text{lepton charge}$
- $\sigma(qg \rightarrow t) \cdot (t \rightarrow Wb) < 3.9 \text{ pb} @ 95\% \text{ CL}$
- $B(t \rightarrow ug) < 5.7 \cdot 10^{-5}$
- $B(t \rightarrow cg) < 2.7 \cdot 10^{-4}$ World best!





W polarization in $t\bar{t}$ decays

ATLAS-CONF-2011-122 $\int \mathcal{L} = 0.70 \text{ fb}^{-1}$

Θ^* \equiv helicity angle of lepton in W-decay from top.

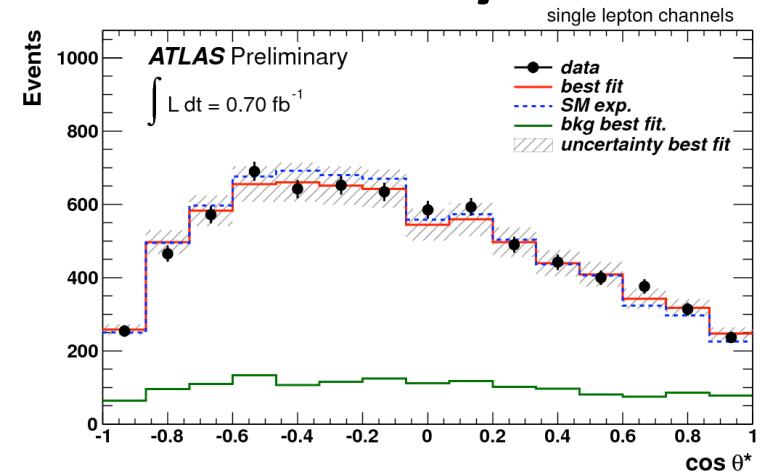
- Uses both di-lepton and (e, μ)+jets events.

$$\frac{1}{\Gamma} \frac{d\Gamma}{d \cos \theta^*} = \frac{3}{8} (1 + \cos \theta^*)^2 F_R + \frac{3}{8} (1 - \cos \theta^*)^2 F_L + \frac{3}{4} (1 - \cos^2 \theta^*) F_0$$

NNLO QCD calculations (Czarnecki, Korner, Piclum)
 $F_0 = 0.687 \pm 0.005$, $F_L = 0.311 \pm 0.005$, $F_R = 0.0017 \pm 0.0001$

Under assumption that $F_R \sim 0$, ATLAS measures

$F_0 = 0.75 \pm 0.08 \text{ (stat+syst)}$, $F_L = 0.25 \pm 0.08 \text{ (stat+syst)}$





Limits on anomalous couplings from W polarization



- New physics can be parameterized in terms of an effective Lagrangian.

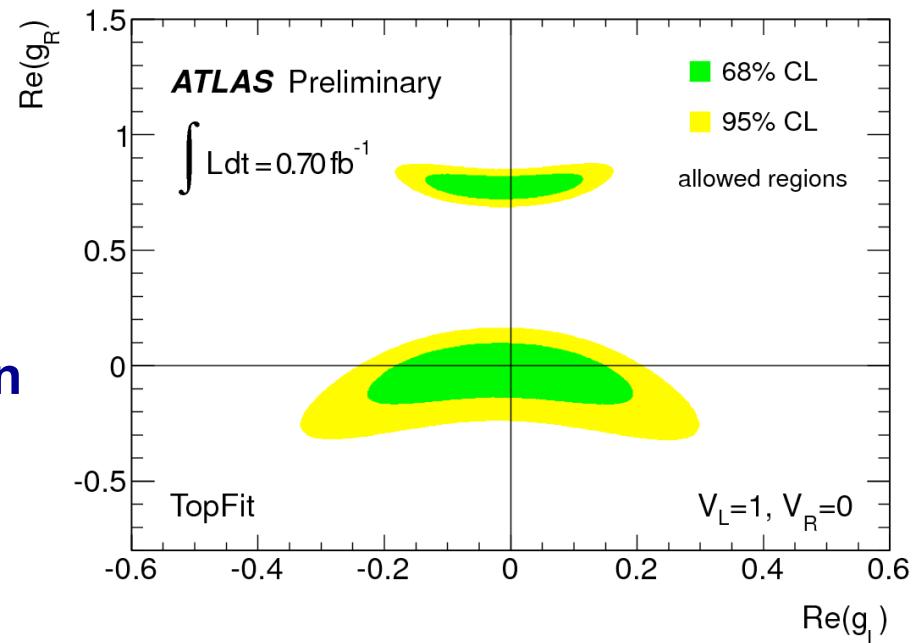
$$\mathcal{L} = -\frac{g}{\sqrt{2}} \bar{b} \gamma^\mu (V_L P_L + V_R P_R) t W_\mu^- - \frac{g}{\sqrt{2}} \bar{b} \frac{i \sigma^{\mu\nu} q_\nu}{M_W} (g_L P_L + g_R P_R) t W_\mu^- + h.c.$$

where $V_L = V_{tb} + C_{\phi q}^{(3,3+3)} \frac{v^2}{\Lambda^2}$

$$V_R = \frac{1}{2} C_{\phi\phi}^{33*} \frac{v^2}{\Lambda^2} \quad g_L = \sqrt{2} C_{dW}^{33} * \frac{v^2}{\Lambda^2}$$

$$g_R = \sqrt{2} C_{uW}^{33} \frac{v^2}{\Lambda^2}$$

Constraints can be placed on these anomalous couplings as well.





Summary and Outlook

In 2011, ATLAS collected a large number of top events.

- **$t\bar{t}$ production**
 - **Cross-section:** uncertainty dominated by systematics, smaller than theory uncertainty
 - **Mass:** uncertainty dominated by systematics. Considerable effort needs to be invested to reach Tevatron precision.
 - **Properties:** so far all consistent with SM predictions.
- **Single top**
 - **Cross section:** measurement/limits on all channels.
 - Worlds best limit on FCNC $B(t \rightarrow u(c) + g)$
- I haven't shown a lot of searches made.

Outlook (1): (2011 data set)

Use full 5 fb^{-1} . Many analyses still in progress.
improved simulation, larger data samples
Systematics improving as we study data more closely.



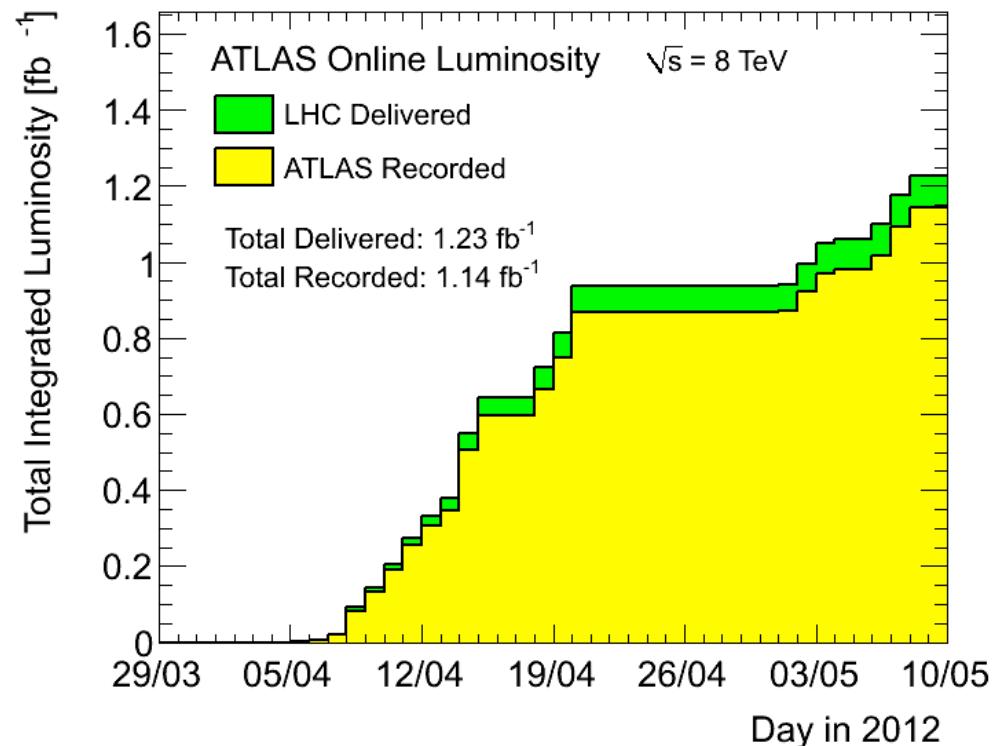
Outlook (2): 2012 prospects

2012 Data taking has begun

Already $> 1 \text{ fb}^{-1}$

Peak instantaneous
luminosity has already
exceeded 2011.

Much more to come!



<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults>