Highlights from the TOP 2015 conference

Top properties

Cécile Deterre

LHC discussion

DESY, November 2nd 2015

New results for TOP 2015

ATLAS

- TOPQ-2014-14: Search for flavour-changing neutral current top quark decays $t \to Hq$ in pp collisions at $\sqrt{s}$=8 TeV with the ATLAS detector
- TOPQ-2012-20: Measurement of the production cross-section of a single top quark in association with a W boson at 8 TeV with the ATLAS experiment
- TOPQ-2014-15: Measurement of the differential cross-section of highly boosted top quarks as a function of their transverse momentum using the ATLAS detector in $\sqrt{s}$=8 TeV proton-proton collisions
- TOPQ-2015-06: Measurements of top-quark pair differential cross-sections in the lepton+jets channel in pp collisions at $\sqrt{s}$=8 TeV using the ATLAS detector
- TOPQ-2013-12: Search for anomalous couplings in the Wtb vertex from the measurement of double differential angular decay rates of single top quarks produced in the t-channel with the ATLAS detector
- TOPQ-2013-10: Measurement of the correlations between the polar angles of leptons from top quark decays in the helicity basis at $\sqrt{s}$=7 TeV using the ATLAS detector

3 new CONF notes (see also below)

- ATLAS-CONF-2015-047: Evidence for single top-quark production in the s-channel in proton-proton collisions at $\sqrt{s}$=8 TeV with the ATLAS detector using the Matrix Element Method
- ATLAS-CONF-2015-048: Measurement of the charge asymmetry in highly boosted top-quark pair production in $\sqrt{s}$= 8 TeV pp collision data collected by the ATLAS experiment
- ATLAS-CONF-2015-049: Measurements of the $t\bar{t}$ production cross-section in the dilepton and lepton-plus-jets channels and of the ratio of the $t\bar{t}$ and Z boson cross-sections in pp collisions at $\sqrt{s}$=13 TeV with the ATLAS detector

1 new PUB note

- ATL-PHYS-PUB-2015-042: Impact of fragmentation modelling on the jet energy and the top-quark mass measurement using the ATLAS detector

CMS

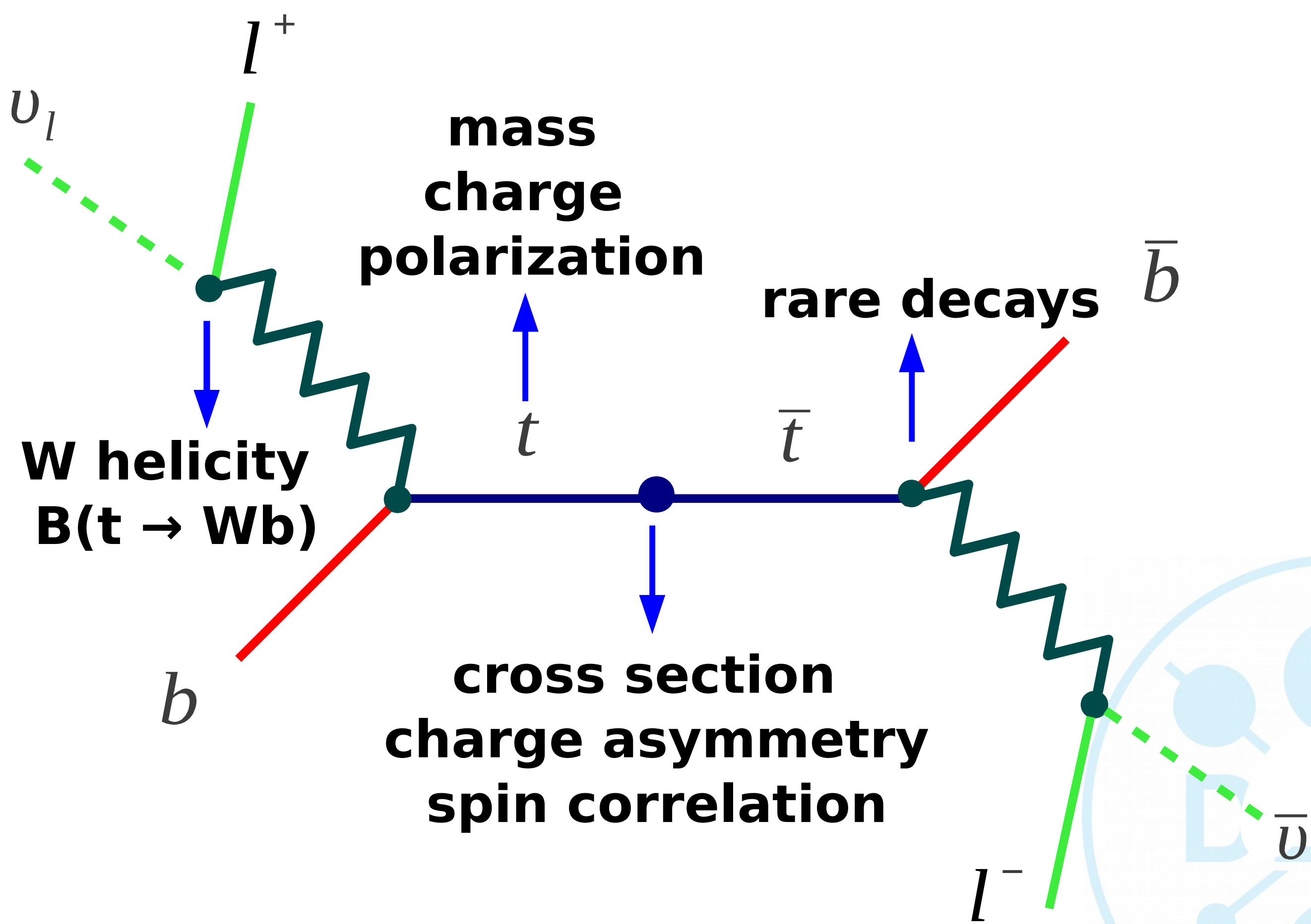
NEW September 2015	TOP-15-004	Measurement of the t-channel single top-quark cross section at 13 TeV	42/pb	PhysicsResultsTOP15004	CMS PAS TOP-15-004
NEW September 2015	TOP-15-005	Measurement of the inclusive and differential top quark pair production cross sections in lepton + jets final states at $\sqrt{s}$ = 13 TeV	42/pb	PhysicsResultsTOP15005	CMS PAS TOP-15-005
NEW August 2015	TOP-15-010	First measurement of the differential cross section for ttbar production in the dilepton final state at $\sqrt{s}$ = 13 TeV	42/pb	PhysicsResultsTOP15010	CMS PAS TOP-15-010
NEW August 2015	TOP-15-003	Measurement of the top quark pair production cross section in proton-proton collisions at $\sqrt{s}$ = 13 TeV with the CMS detector	42/pb	PhysicsResultsTOP15003	CMS PAS TOP-15-003

NEW Sep 2015	TOP-15-007	Fiducial t-channel single-top cross section at $\sqrt{s}$ = 8 TeV	19.7/fb	public	CMS PAS TOP-15-007
NEW Sep 2015	TOP-14-023	Measurements of ttbar Spin Correlations and Top-Quark Polarization Using Dilepton Final States in pp Collisions at $\sqrt{s}$ = 8 TeV	19.7/fb	public	CMS PAS TOP-14-023
NEW Sep 2015	TOP-15-002	Measurement of the top-quark mass from b-jet energy spectrum	19.7/fb	public	CMS PAS TOP-15-002
NEW Aug 2015	TOP-13-004	Measurements of the inclusive top-quark pair production cross section in the eμ decay channel in pp collisions at $\sqrt{s}$= 7 and 8 TeV	5 and 19.7/fb	public	CMS PAS TOP-13-004
NEW Aug 2015	TOP-14-012	Measurement of the differential ttbar production cross section for high-pT top quarks in e/μ+jets final states at $\sqrt{s}$ = 8 TeV	19.7/fb	public	CMS PAS TOP-14-012

NEW September 2015	TOP-14-022	Measurement of the top quark mass using proton-proton data at $\sqrt{s}$ = 7 and 8 TeV	2012 (19.7/fb)	CERN-PH-EP-2015-234 arXiv:1509.04044 submitted to PRD
NEW September 2015	TOP-14-018	Measurement of the ttbar production cross section in the all-jets final state in pp collisions at $\sqrt{s}$ = 8 TeV	2012 (18.4/fb)	CERN-PH-EP-2015-243 arXiv:1509.06076 submitted to PRD
NEW August 2015	TOP-13-013	Measurement of the charge asymmetry in top quark pair production in pp collisions at $\sqrt{s}$ = 8 TeV using a template method	2012 (19.7/fb)	CERN-PH-EP-2015-189 arXiv:1508.03862 submitted to PRD

Top properties

- The top quark is very special, and could help to find and shed light on BSM physics.
- Many of its properties are being studied at the LHC...



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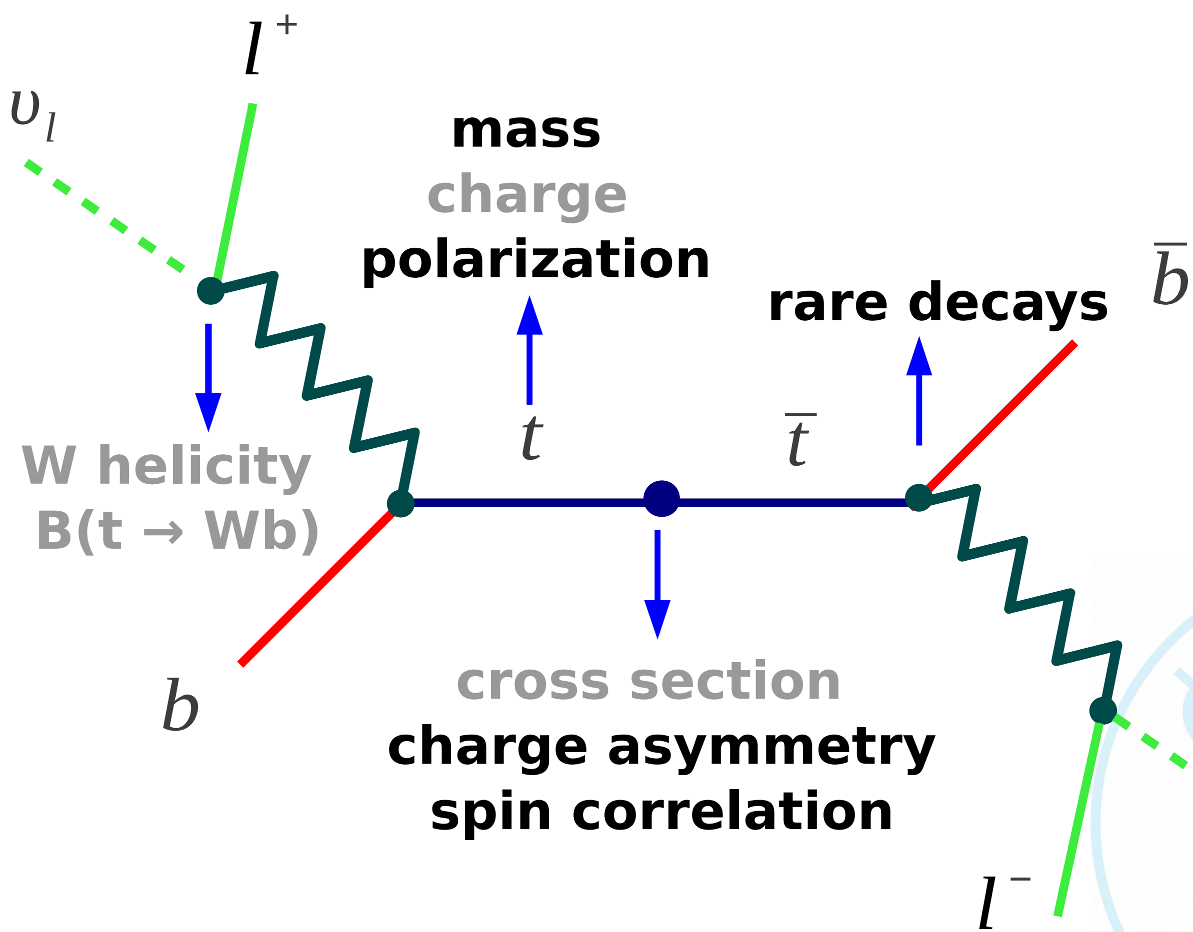


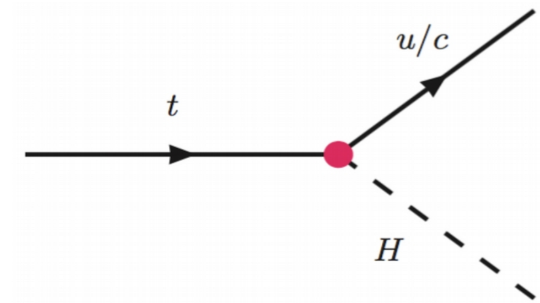
Overview

- **FCNC searches**
  - CMS: $t \rightarrow Hq$ ($H \rightarrow \gamma\gamma$)
  - ATLAS: $t \rightarrow Hq$ combination
- **Charge asymmetry**
  - ATLAS: measurement in boosted topologies
  - CMS: template method
- **Spin correlation and polarization** at CMS
- **Color flow** in ATLAS
- **Alternative mass measurements**
  - pole mass measurements from ATLAS and CMS
  - CMS: measurement from the b-jet energy spectrum

$\rightarrow$ ***all run-1 results***

FCNC searches, $t \to Hq$ channel

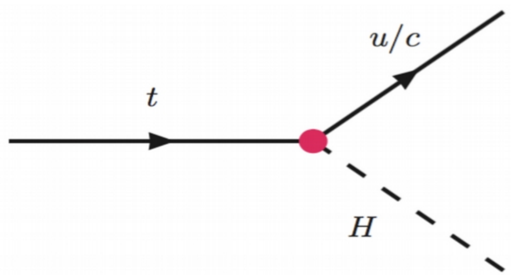
- Forbidden at tree level, higher level suppressed by the GIM mechanism
  - SM predicts BR ~ 10^{-14}
  - BSM could increase the BR up to 10^{-3}
  - if observed, definite sign of new physics!



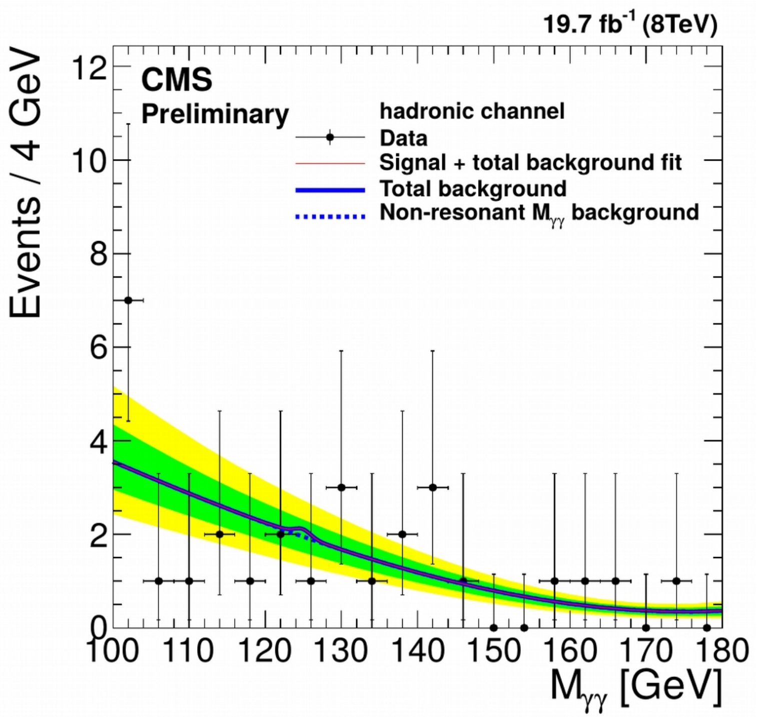
- Use all decay channels: $H \to \gamma\gamma$, $b\bar{b}$, $WW/ZZ/\tau\tau$ channel and combine them to get most sensitive limits
- Best LHC limits

Experiment	BR($t \to Hu$)	BR($t \to Hc$)	Channels	Reference
ATLAS	0.45 (0.29) %	0.46 (0.25) %	$H \to b\bar{b} + \gamma\gamma + WW/\tau\tau$	arXiv:1509.06047
CMS	0.42 (0.65) %	0.47 (0.71) %	$H \to \gamma\gamma$	CMS-PAS-TOP-14-019

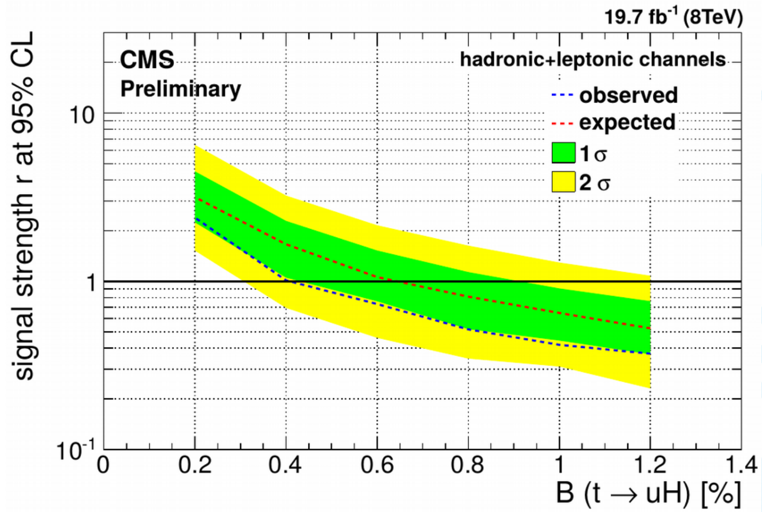
FCNC searches, t → Hq channel - CMS



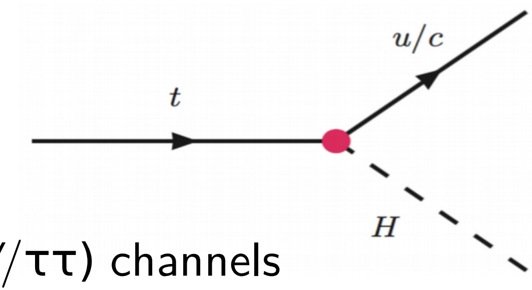
- Best limit obtained in the H → γγ channel, using both top decay channels.
- Select events with 2 photons, 1 b-jet and ≥ 4 jets or ≥ 1 lepton and ≥ 2 jets + additional constraints on the reconstructed top and W masses
- Main background: non resonant γγ+jets events fit from data



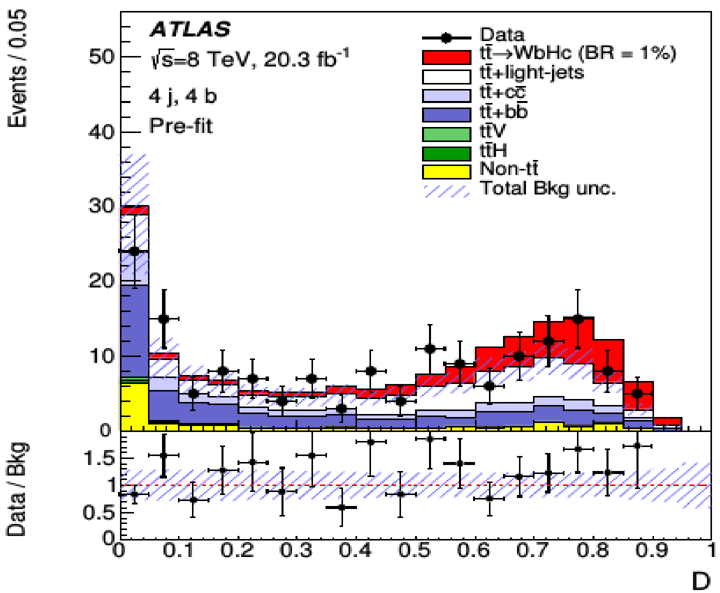
	Hadronic channel	Leptonic channel
Data	29	8
Resonant diphoton background	0.152 ± 0.021 (stat.)	0.038 ± 0.008 (stat.)
Non-resonant diphoton background	28.9 ± 5.4 (stat.)	8.0 ± 2.8 (stat.)
expected signal yields for $\mathcal{B}$ (t → cH) = 1%	6.26 ± 0.07 (stat.)	1.91 ± 0.04 (stat.)
expected signal yields for $\mathcal{B}$ (t → uH) = 1%	7.09 ± 0.08 (stat.)	2.02 ± 0.04 (stat.)

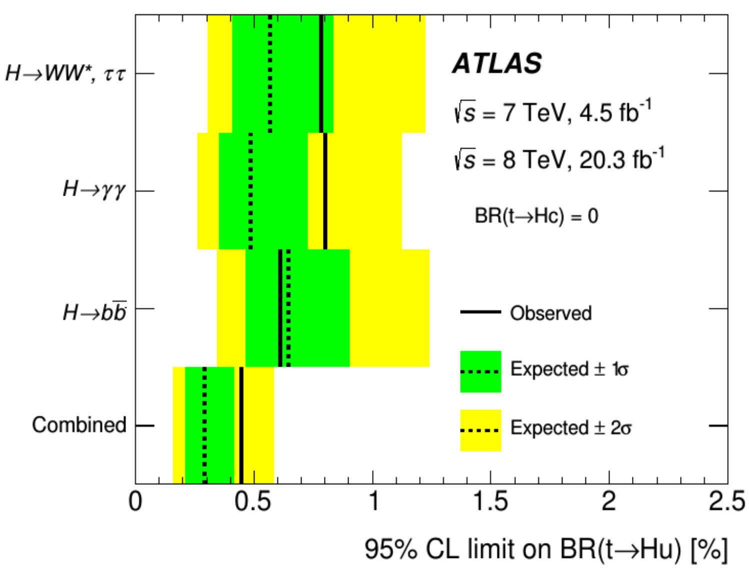


FCNC searches, $t \rightarrow Hq$ channel - ATLAS



- Similar sensitivities obtained in the $H \rightarrow b\bar{b}$, $\gamma\gamma$ and multilepton ($WW/\tau\tau$) channels
  $\rightarrow$ combination of the limits





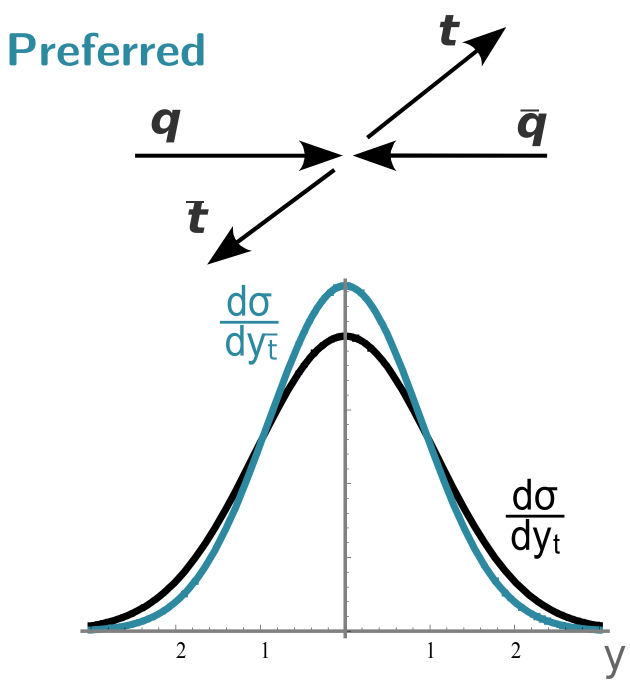
- New for TOP: **$H \rightarrow b\bar{b}$ channel**
  - select events with == 1 lepton, ≥ 4 jets and ≥ 2 b-tags
  - categorization of events depending on N_{jets} and $N_{b\text{-tags}}$
    $\rightarrow$ most sensitive: (4j, 3b), (4j, 4b) ($t\bar{t} \rightarrow WbHu, WbHc$)
  - discriminant between signal and main bkg in each channel

$$(t\bar{t}+\text{light}/cc/bb):\ D(\mathbf{x}) = \frac{P^{\text{sig}}(\mathbf{x})}{P^{\text{sig}}(\mathbf{x}) + P^{\text{bkg}}(\mathbf{x})}$$

    with probabilities based on kinematic and b-tagging
  - likelihood fit with nuisance parameters to extract the signal strength

Top charge asymmetry measurement

- Quantifies the excess of tops emitted in the direction of the incoming quark



- Define asymmetries based on tops and leptons:

$$A_C(t\bar{t}) = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}, \text{ with } \Delta|y| = |y_t| - |y_{\bar{t}}|$$

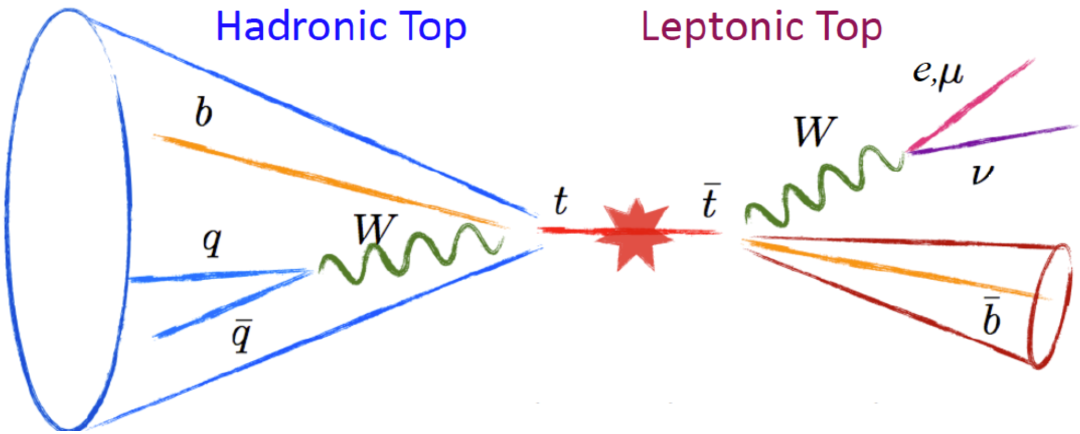
$$A_C(l^+l^-) = \frac{N(\Delta|\eta| > 0) - N(\Delta|\eta| < 0)}{N(\Delta|\eta| > 0) + N(\Delta|\eta| < 0)}, \text{ with } \Delta|\eta| = |\eta_{l^+}| - |\eta_{l^-}|$$

- SM prediction $\sim 1\%$

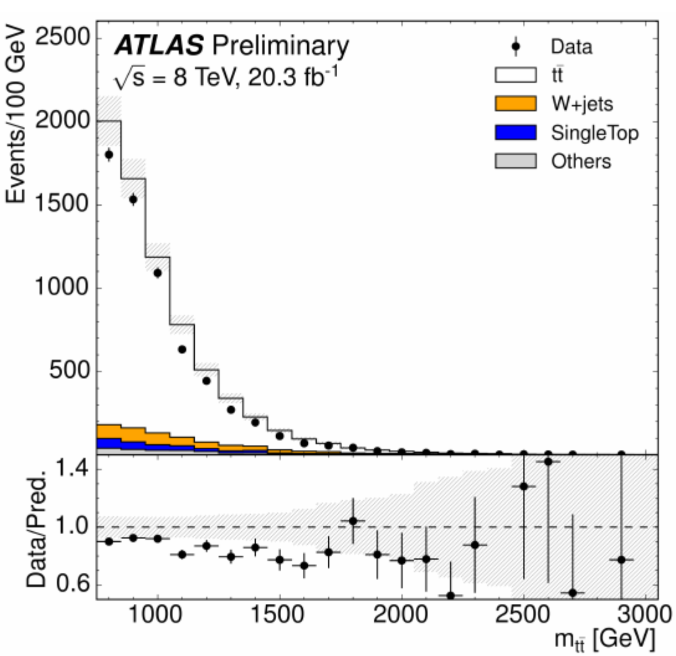
- "**Traditional**" method: unfold the $\Delta|y|$ distribution and measure the asymmetry
- Two slightly different results shown at TOP:
  - measurement in the ljets channel with **boosted topologies** from ATLAS [ATLAS-CONF-2015-048]
  - **template method** from CMS in the resolved ljets channel [CMS-PAS-TOP-13-013]

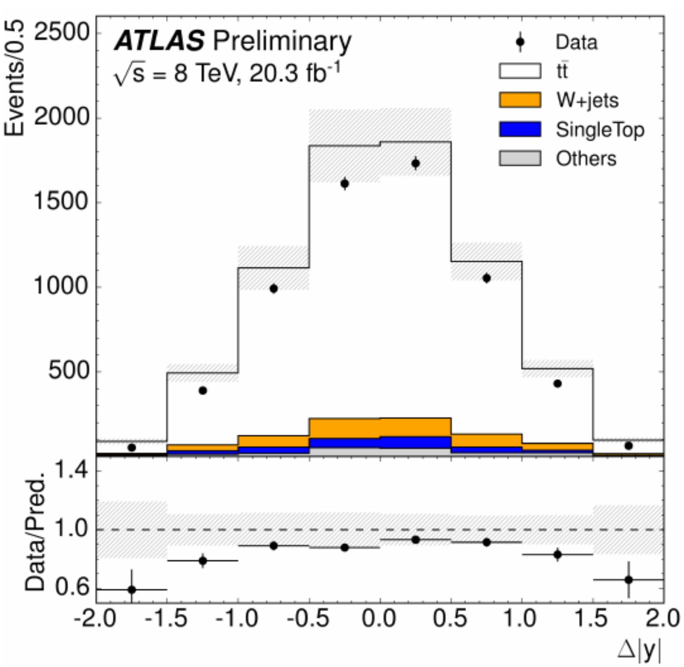
Asymmetry in the boosted ljets channel - ATLAS

- **Select events** with exactly 1 lepton and:
  - ≥ 1 small-R jet (with ≥ 1 b-tag)
  - == 1 large-R jet ($p_T > 300$ GeV)
  - $m_{ttbar} \geq 750$ GeV + MET and m_T^W cuts



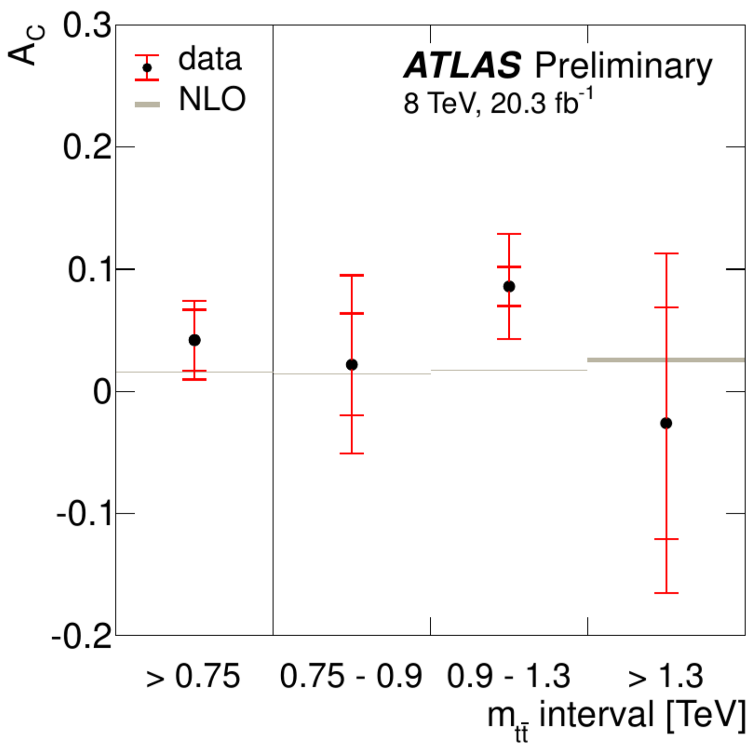
- **Reconstruct** leptonic top by using the highest p_T jet and solving for the neutrino momentum assuming the W mass

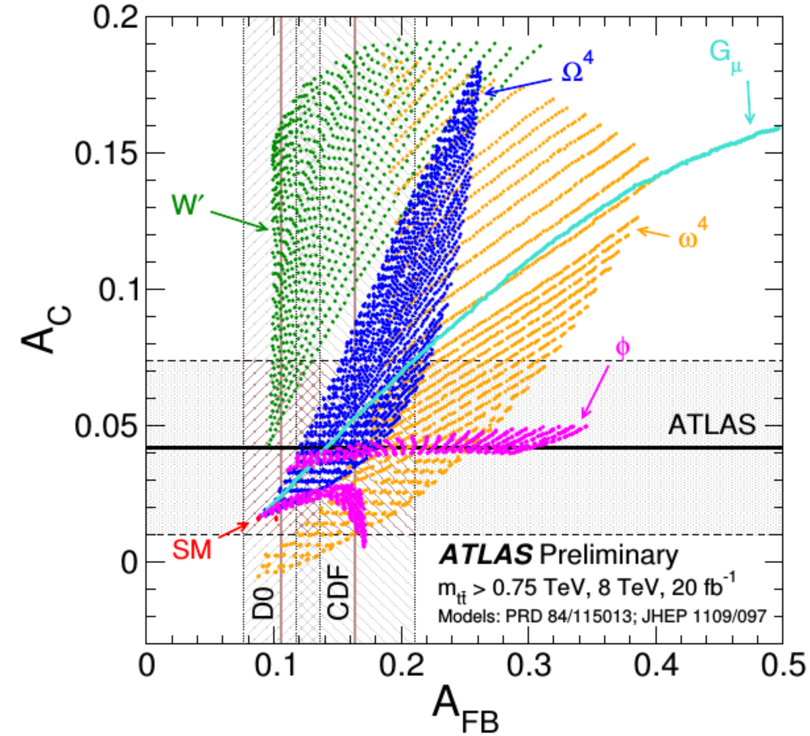




Asymmetry in the boosted ljets channel - ATLAS

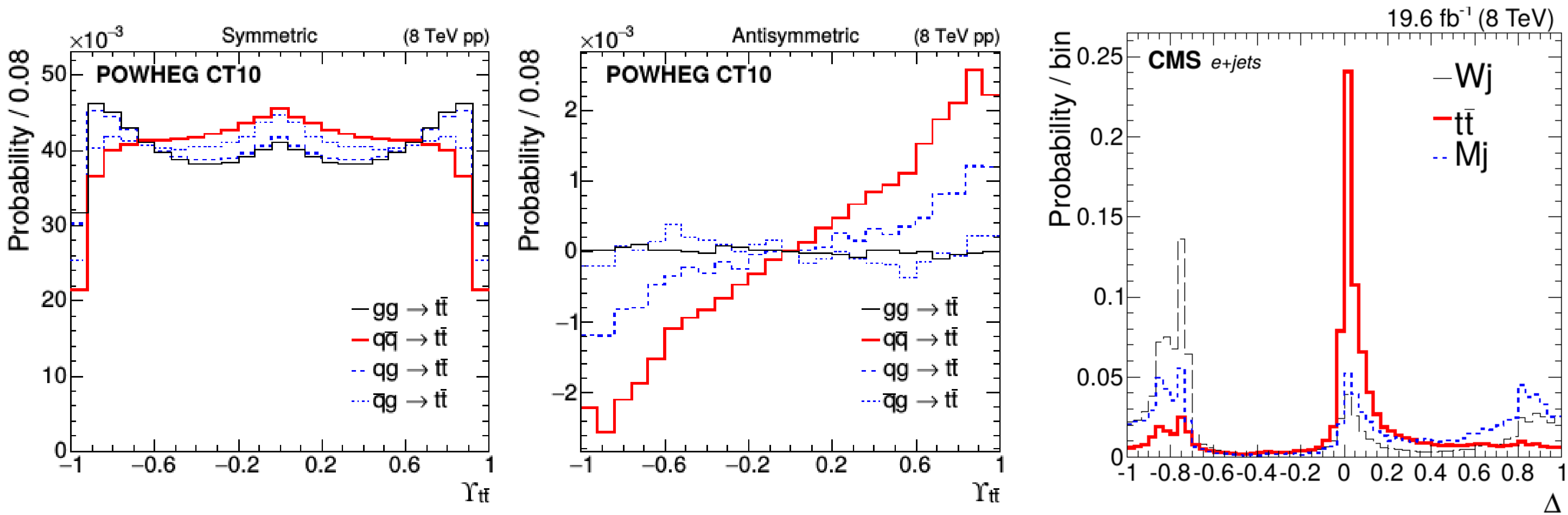
- Perform **inclusive** and **differential** measurement (as a function of $m_{t\bar{t}}$)
- Unfold distributions using **fully Bayesian** technique
- Results in agreement with SM
  - extend significantly the $m_{t\bar{t}}$ range
  - statistics dominated





Asymmetry with a template method - CMS

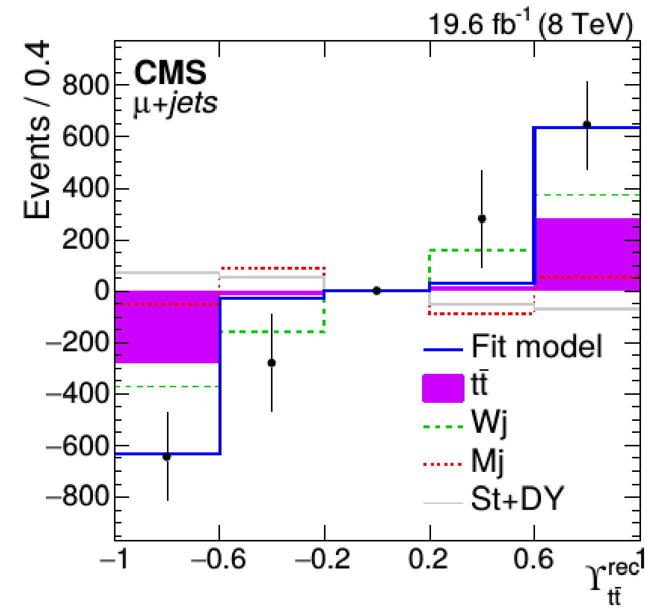
- Standard ljets selection
- Define $\Upsilon_{t\bar{t}} = \tanh \Delta|y|_{t\bar{t}}$ and fit the symmetric and asymmetric parts of the distribution

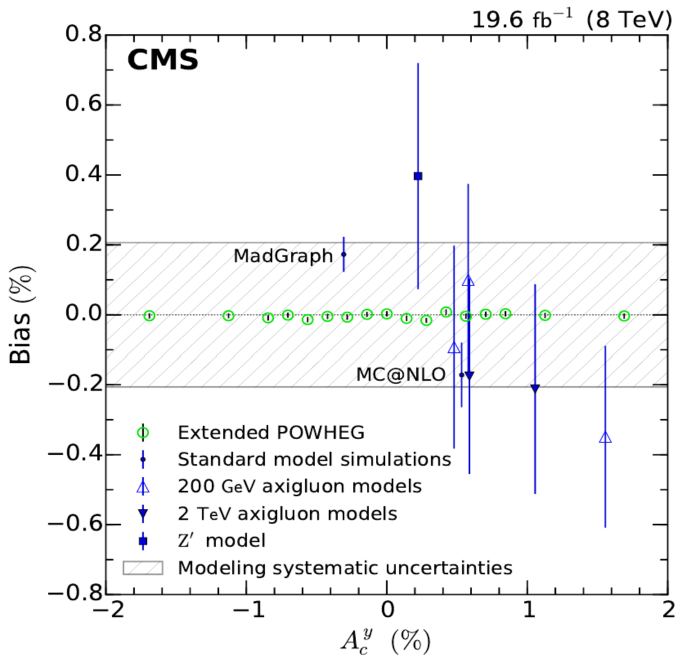


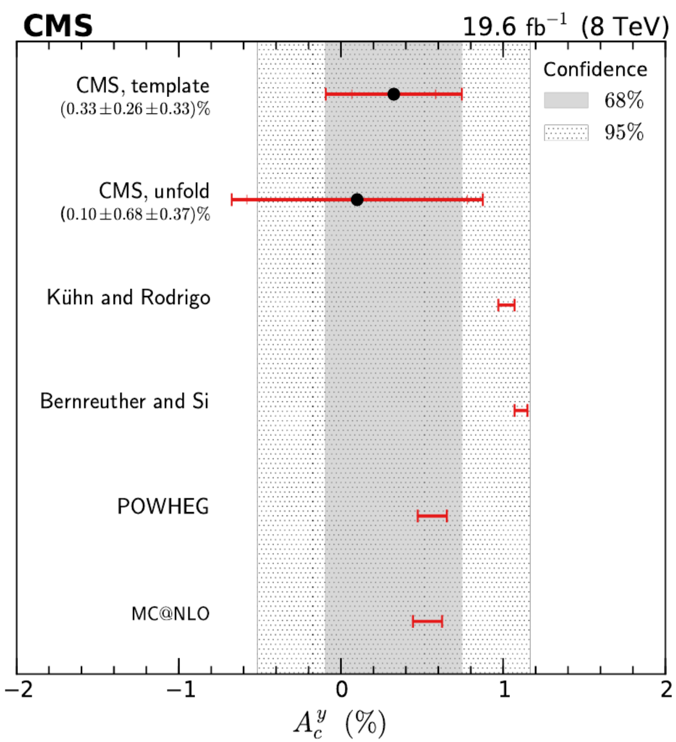
- Reconstruct the tops with a kinematic fit
- Separate $t\bar{t}$, W+jets and multijet events using a discriminant Δ based on the W M_T, kinematic and b-tagging likelihoods

Asymmetry with a template method - CMS

- First fit the Δ distribution, then the $Y_{t\bar{t}}$ distribution and **extract the asymmetry**
- Check the **bias** of the method using various models.



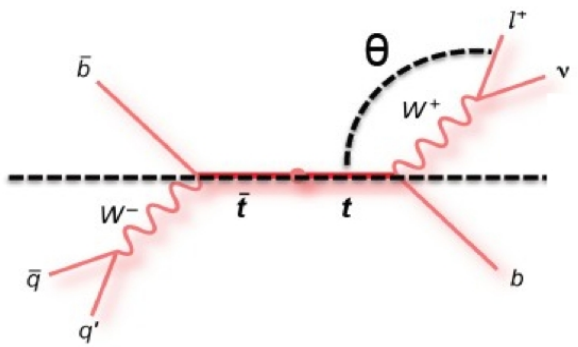




- **Result**: Ac = [0.33 ± 0.26 ± 0.33] %
  - in agreement with SM prediction
  - **most precise measurement**, with slightly higher model dependency

Spin correlation and polarization

- Angular distributions of top pair decay products affected by their polarization and spin correlations
  - in the **SM, top pairs are unpolarized but their spins are correlated**
  - could be affected by BSM models



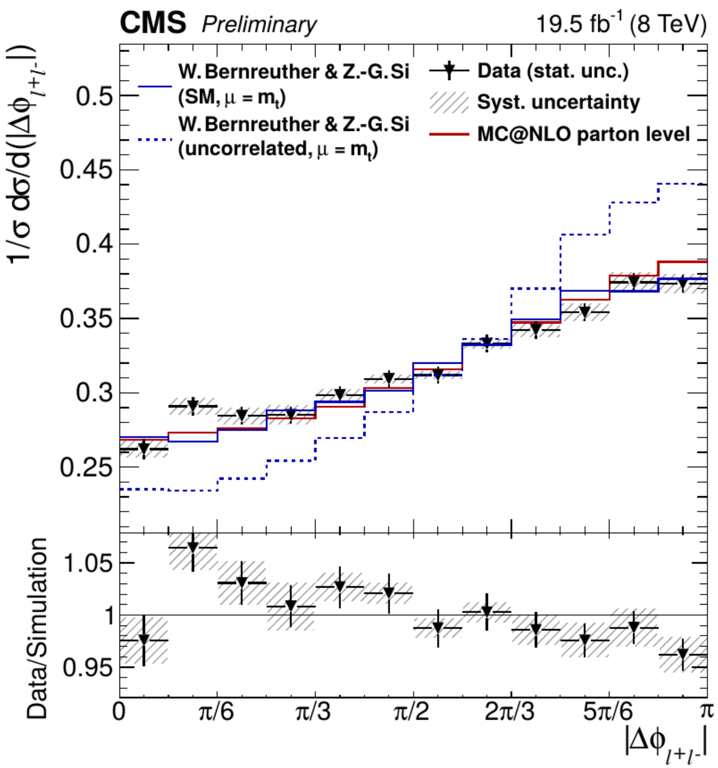
- **Observables** based on the angles:
  - Φ between the two leptons $\to$ spin
  - φ between the leptons in the rest frame of their parent $\to$ spin
  - θ between the lepton and the top in the helicity rest-frame, $\cos\theta_{+/-} \to$ pol, $\cos\theta_{+}\cos\theta_{-} \to$ spin
- **Methods** for the measurement:
  - template fit to samples with different spin/polarization
  - unfold the distribution and compute the asymmetries:

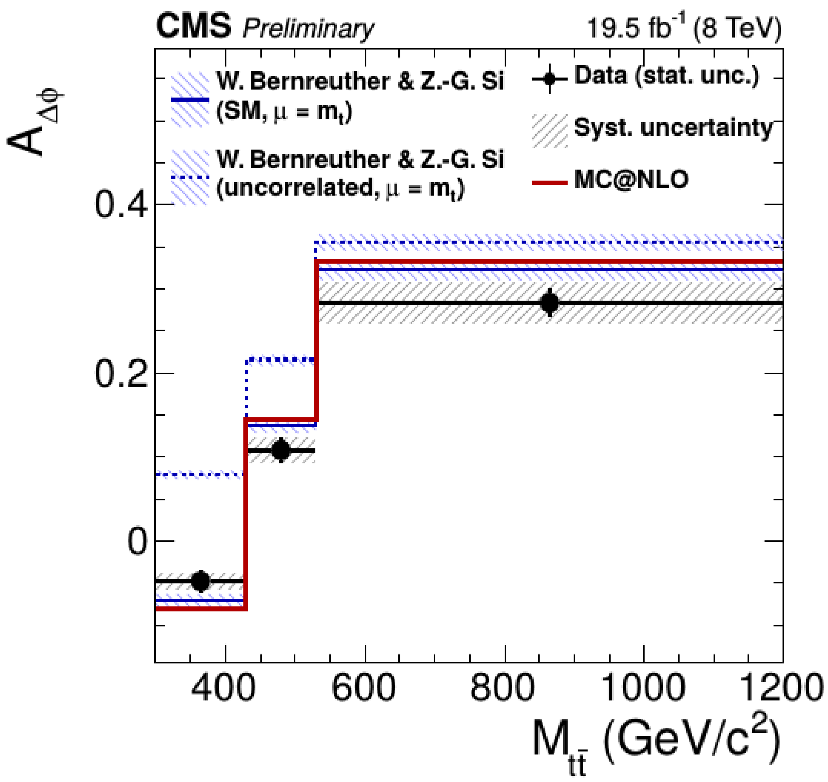
$$A_P = \frac{N\left[\cos\theta^\star_\ell > 0\right] - N\left[\cos\theta^\star_\ell < 0\right]}{N\left[\cos\theta^\star_\ell > 0\right] + N\left[\cos\theta^\star_\ell < 0\right]} \qquad A_{\cos\varphi} = \frac{N\left[\cos\varphi > 0\right] - N\left[\cos\varphi < 0\right]}{N\left[\cos\varphi > 0\right] + N\left[\cos\varphi < 0\right]}$$

$$A_{c_1c_2} = \frac{N(c_1c_2 > 0) - N(c_1c_2 < 0)}{N(c_1c_2 > 0) + N(c_1c_2 < 0)} \qquad A_{\Delta\phi} = \frac{N(|\Delta\phi_{\ell^+\ell^-}| > \pi/2) - N(|\Delta\phi_{\ell^+\ell^-}| < \pi/2)}{N(|\Delta\phi_{\ell^+\ell^-}| > \pi/2) + N(|\Delta\phi_{\ell^+\ell^-}| < \pi/2)}$$

Spin correlation and polarization - CMS

- Analysis done in the **dilepton channel** *[CMS-PAS-TOP-14-023]*
- **Differential measurement** versus $m_{t\bar{t}}$, $|y_{t\bar{t}}|$ and $p_{Tt\bar{t}}$





- **Results consistent with SM predictions**
- Limits on **anomalous ttg couplings**: exclude real part of chromo-magnetic dipole moment outside of $-0.050 < \mathrm{Re}(\mu_t) < 0.076$

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[CMS-PAS-TOP-14-023]

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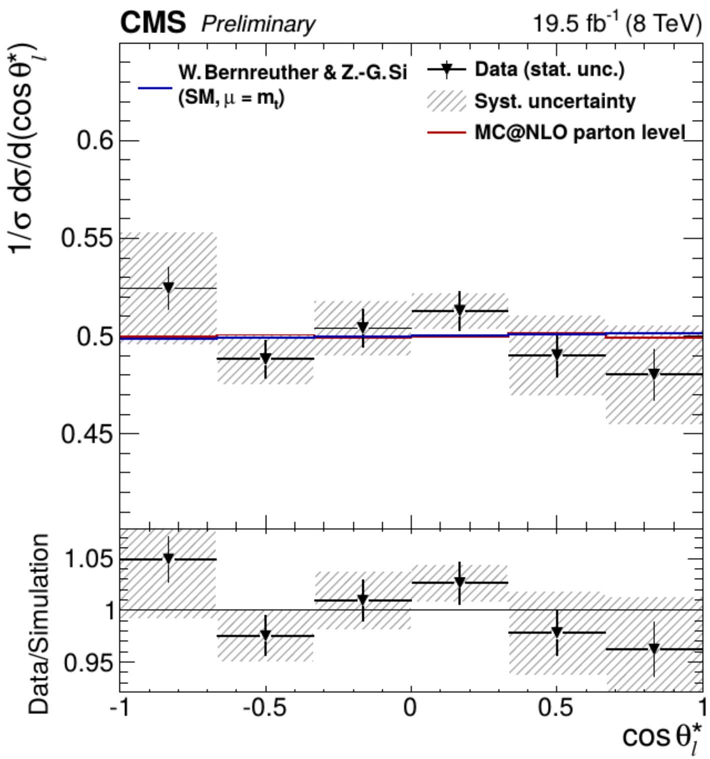

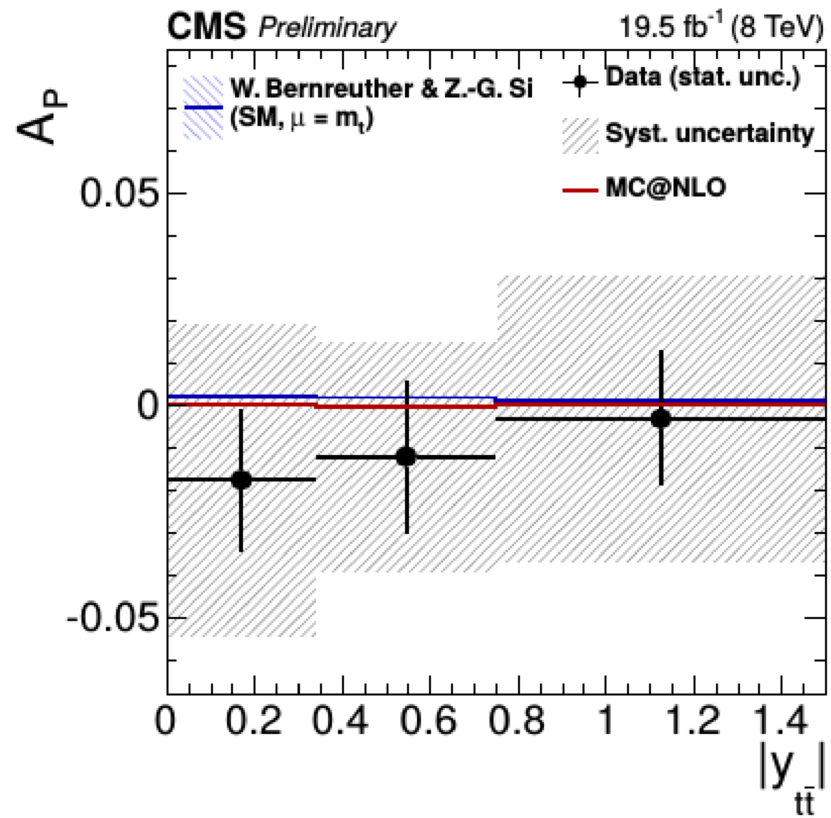

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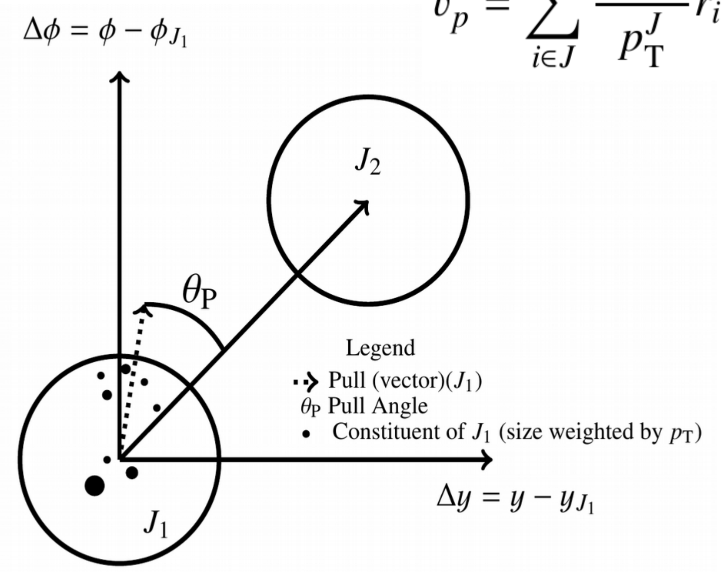
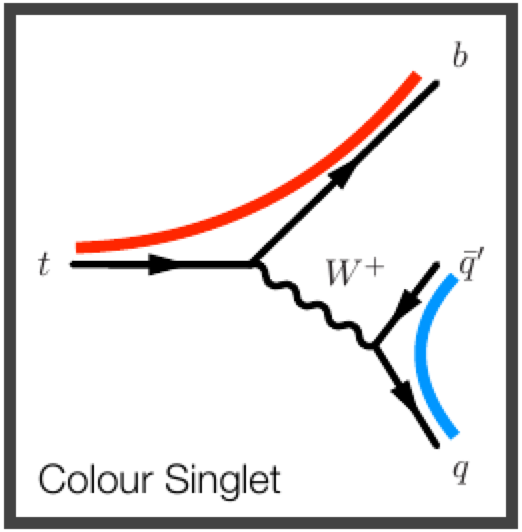
Color flow - ATLAS

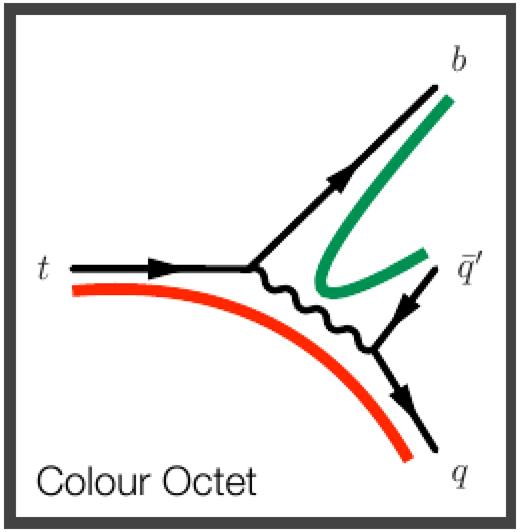
[PLB (2015) 475-493]

- Measurement of the **jet pull angle** as handle on color connection between quarks and gluons initiating jets
- Analysis performed in ljets events
  - select events with ≥ 2 b-tags and ≥ 2 jets not b-tagged
  - 2 highest non b-tagged jets considered to come from W
  - build pull angles using calorimeter clusters (**all-particle**) and tracks associated to a given jet (**charged-particles** pull angle)
  - unfold to particle-level
  - compare to SM and flipped model

$$\vec{v}_p^J = \sum_{i \in J} \frac{p_T^i |\vec{r}_i|}{p_T^J} \vec{r}_i$$





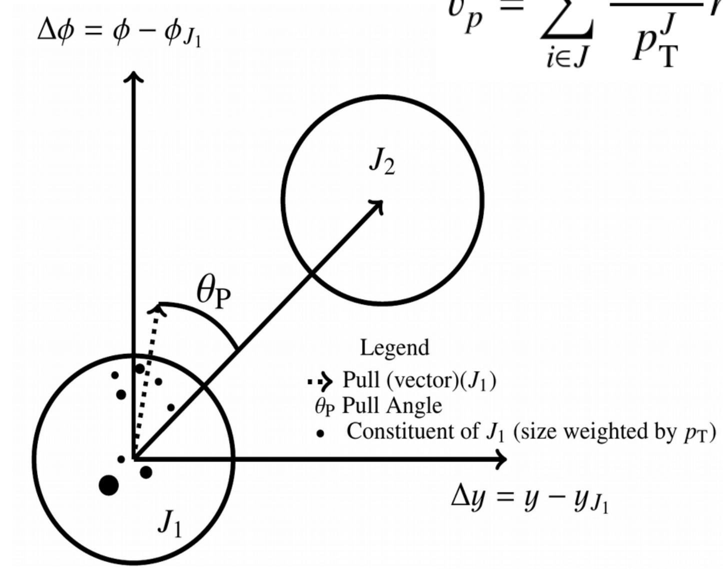


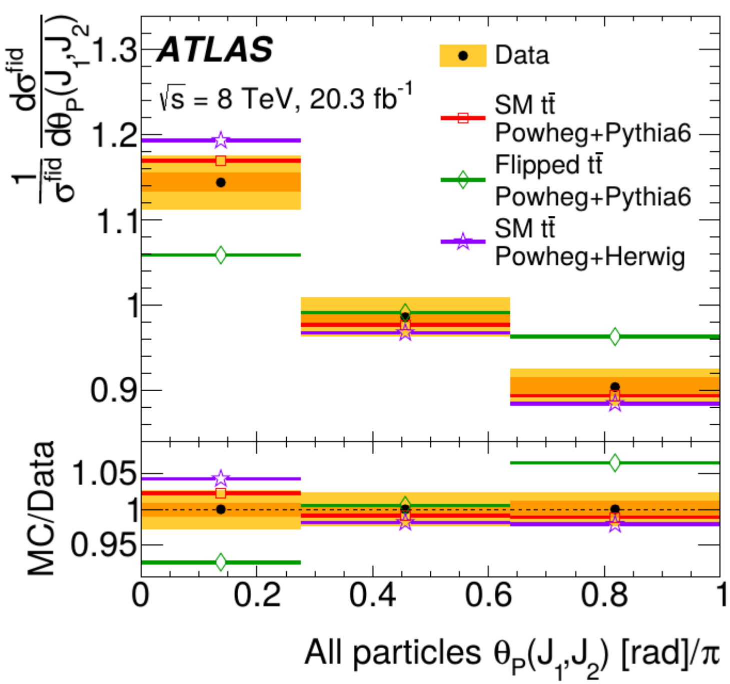
Color flow - ATLAS

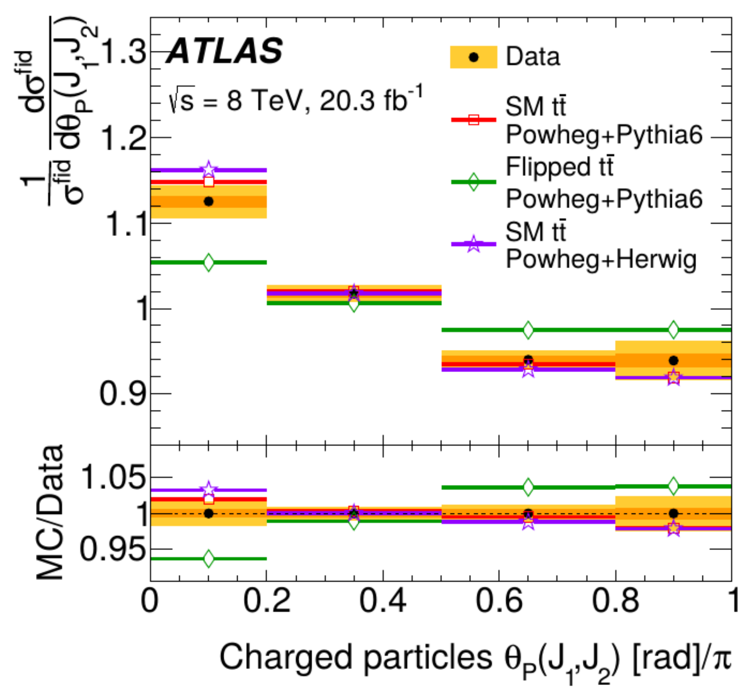
[PLB (2015) 475-493]

- Measurement of the jet pull angle as handle on color connection between quarks and gluons initiating jets
- Analysis performed in ljets events
- Result:
  - data agree with the SM color flow at the level of 0.8σ and differs from the flipped model at 2.9σ

$$\vec{v}_p^{\,J} = \sum_{i\in J} \frac{p_{\mathrm{T}}^i |\vec{r}_i|}{p_{\mathrm{T}}^J}\vec{r}_i$$







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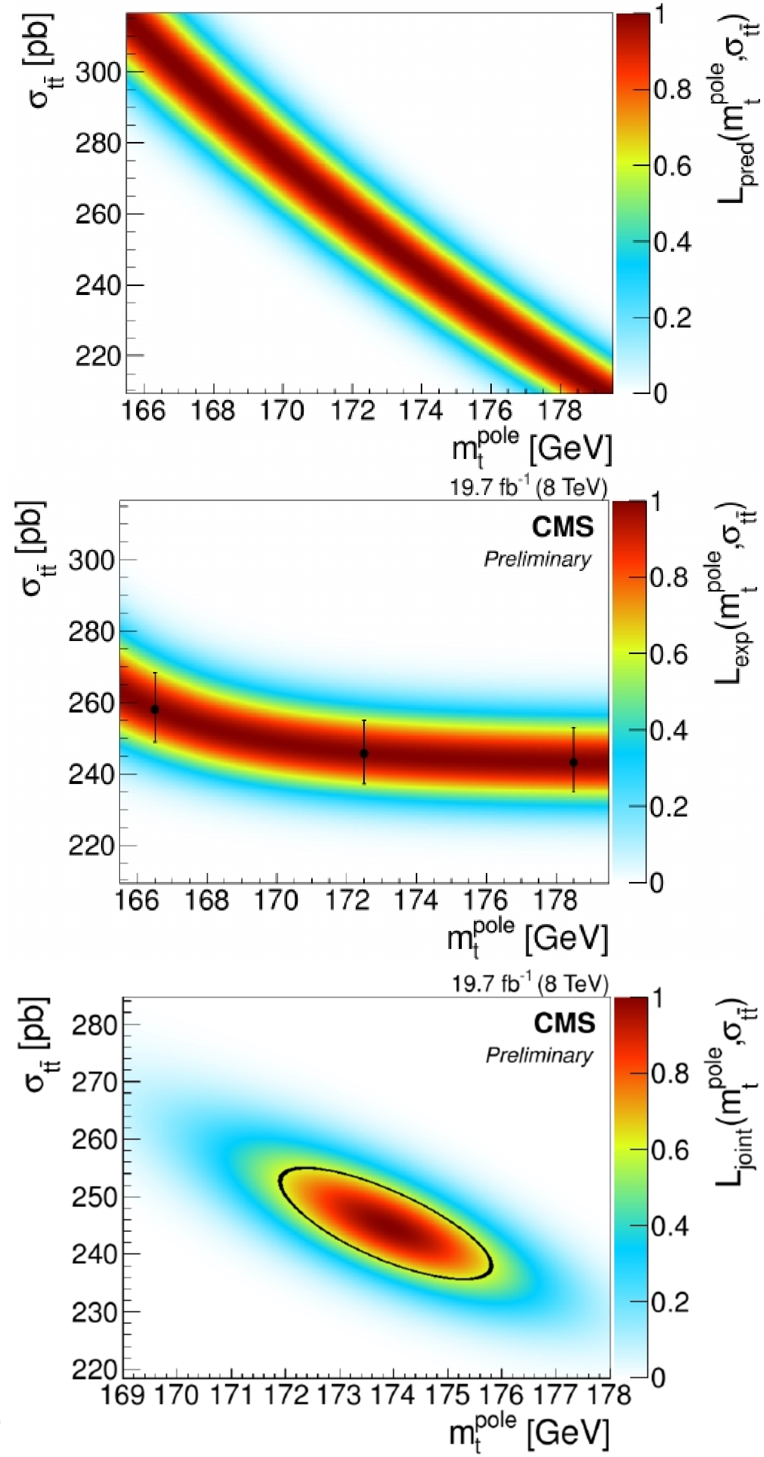
Pole mass extraction - CMS

[CMS-TOP-13-004]

- Inclusive cross-section sensitive to the top mass
- Use cross-section measurement in the eμ channel at 7 and 8 TeV
  - visible cross-section extracted with a likelihood fit to bins of b-jet and jet multiplicity
  - correct to full phase-space
  - repeat for 3 mass hypotheses
- Extract the pole mass:
  - parametrize dependence of the predicted and measured cross-section as a function of m_t for a given PDF
  - maximize the product of the two likelihoods

	m_t
NNPDF3.0	$173.6\pm^{1.7}_{1.8}$ GeV
MMHT2014	$173.9\pm^{1.8}_{1.9}$ GeV
CT14	$174.1\pm^{2.1}_{2.2}$ GeV

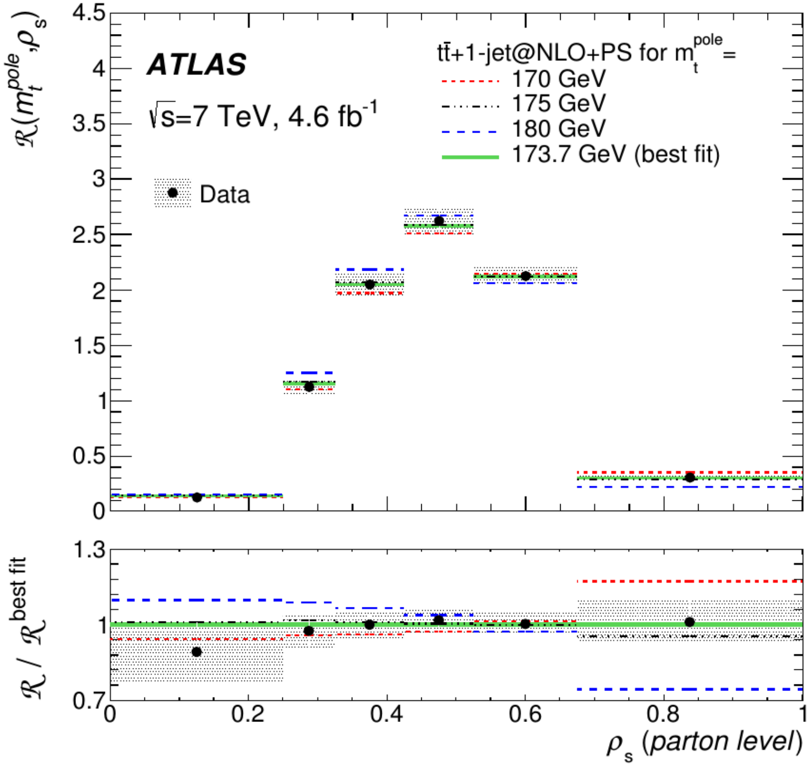


Pole mass extraction - ATLAS

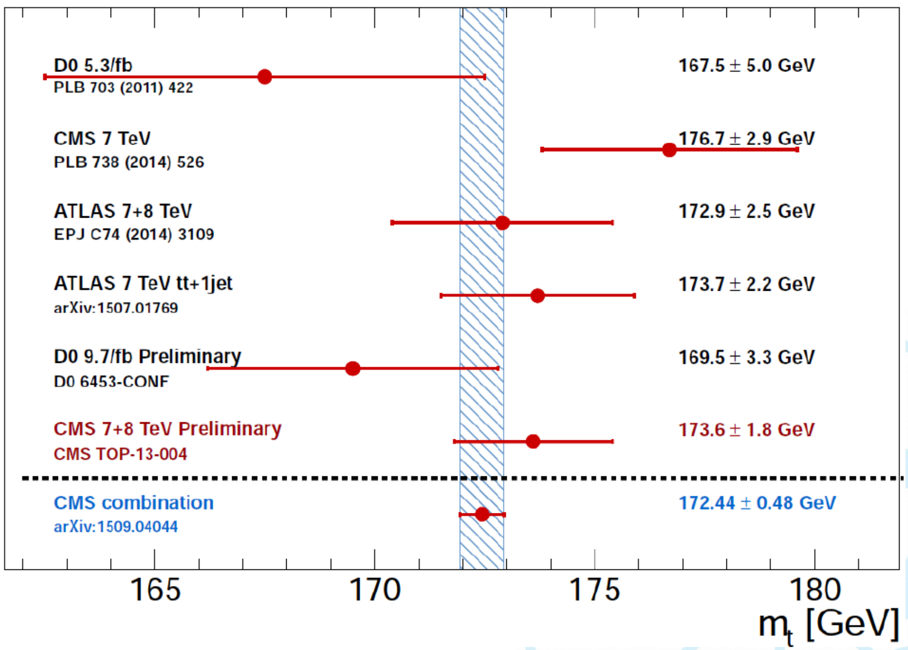
[JHEP 10 (2015) 121]

- Measurement of the $t\bar{t}$+1 jet normalized cross-section as a function of $\rho_s = \frac{2m_0}{\sqrt{s_{t\bar{t}+1\text{-jet}}}}$

  → more sensitive to the top mass than the inclusive cross-section
- Distribution unfolded to parton level and compared to NLO predictions for various pole masses
- Result: $m_t^{\text{pole}} = 173.7 \pm 1.5\ (\text{stat.}) \pm 1.4\ (\text{syst.})^{+1.0}_{-0.5}\ (\text{theory})\ \text{GeV}$

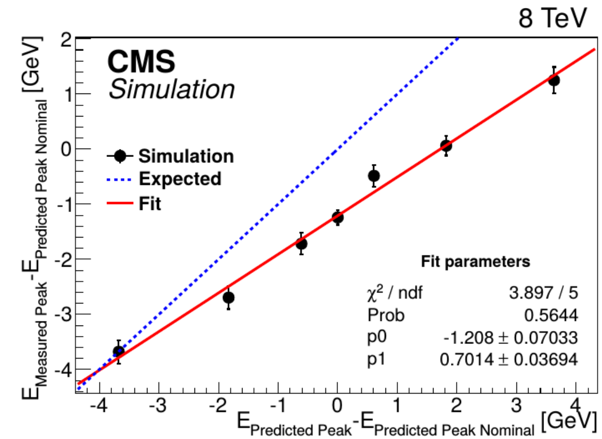


$$\mathcal{R}(m_t^{\text{pole}}, \rho_s) = \frac{1}{\sigma_{t\bar{t}+1\text{-jet}}} \frac{d\sigma_{t\bar{t}+1\text{-jet}}}{d\rho_s}(m_t^{\text{pole}}, \rho_s)$$



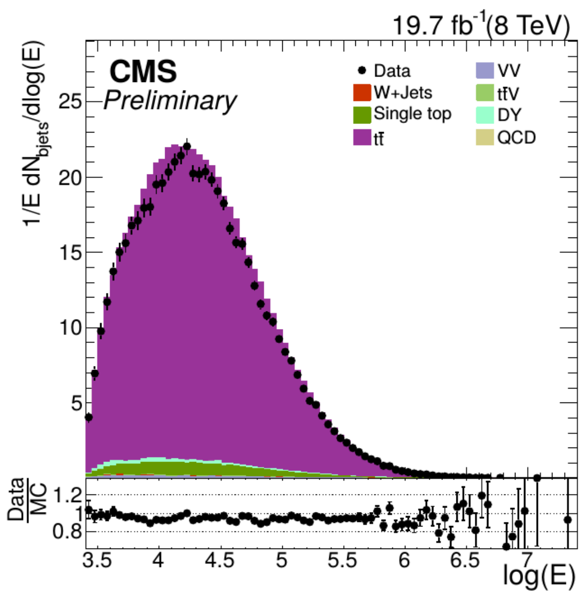
Top mass from the b-jet energy spectrum - CMS

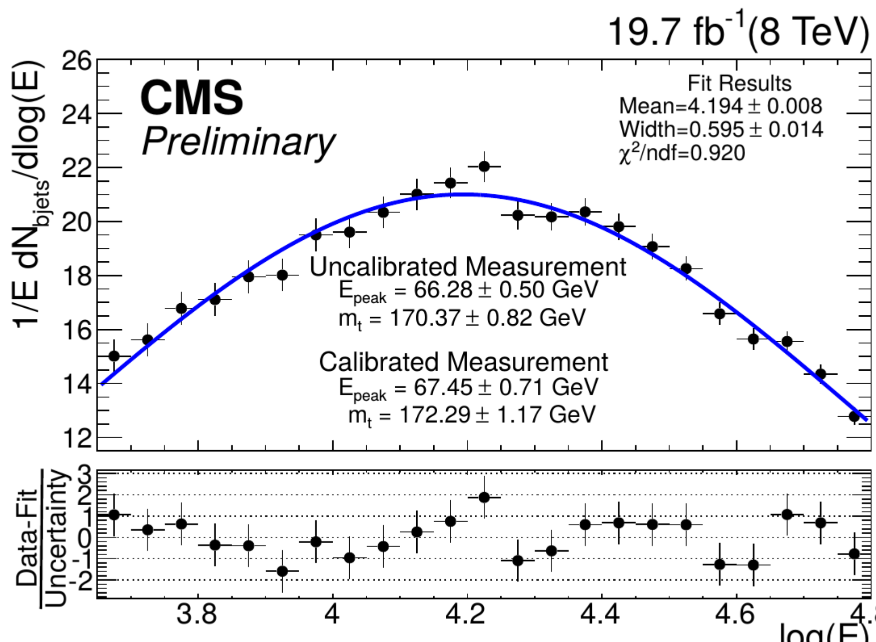
- Position of the peak of the b-jet energy spectrum sensitive to the top mass
  - observable independent of the top boost
    → measurement done in the lab frame, no need to reconstruct the top
  - Agashe et al. *[PRD 88 (2013) 057701]*



- First measurement of this type by CMS in the eμ channel
  - perform Gaussian fit around the peak of the log(E) distribution
  - calibrate the method for selection and reconstruction effects using MC

- Result: $m_{\mathrm{t}} = 172.29 \pm 1.17\,(\mathrm{stat.}) \pm 2.66\,(\mathrm{syst.})\,\mathrm{GeV}$

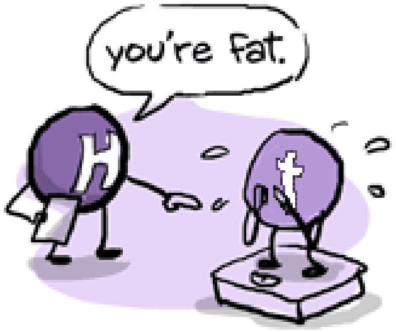




[CMS-PAS-TOP-15-002]

Conclusion

- Many interesting new results for TOP2015!
- Much more than I could show:
  - $\rightarrow$ conference indico
  - $\rightarrow$ CMS public results
  - $\rightarrow$ ATLAS public results



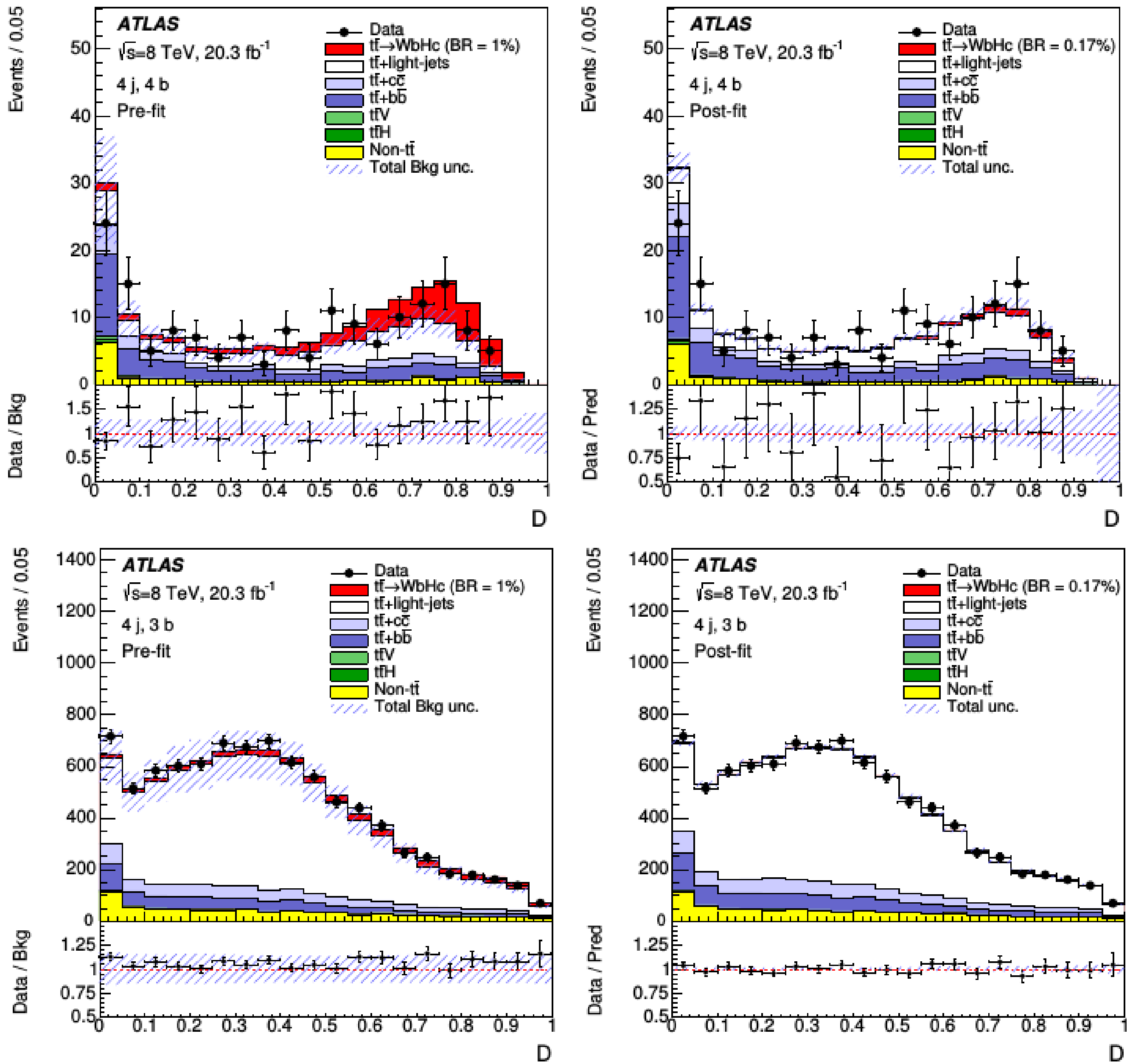
- For properties, all run-1 results for now
  $\rightarrow$ expect the first run-2 results soon (don't miss the DESY seminar tomorrow discussing 13 TeV results from ATLAS and CMS)!

Backup slides

FCNC, t $\rightarrow$ Hq - CMS

source of the systematic uncertainty	hadronic channel	leptonic channel
	Effect on signal yield [%]	
integrated luminosity	2.6	
pileup	0.3	0.8
trigger efficiency	1	
photon identification efficiency	5.2	
electron identification efficiency	-	0.3
muon identification efficiency	-	0.3
$t\bar{t}$ cross section	5.7	
PDF for signal kinematics	5.9	5.2
$t\bar{t}$ p_T reweighting	1.4	3.2
branching fraction $\mathcal{B}$ (H $\rightarrow \gamma\gamma$)	5	
jet identification efficiency	2	
jet energy correction	1.2	1.0
jet energy resolution	2.7	0.4
b tagging efficiency	2.9	3.5
	per photon [%]	
photon energy scale	0.1	
photon energy resolution	0.1	
photon energy scale from the material mis-modeling	0.34	
photon energy scale non-linearity	0.1	
	Effect on background estimation [%]	
production cross section PDF for SM Higgs background	8.1	
production cross section scale for SM Higgs background	9.3	

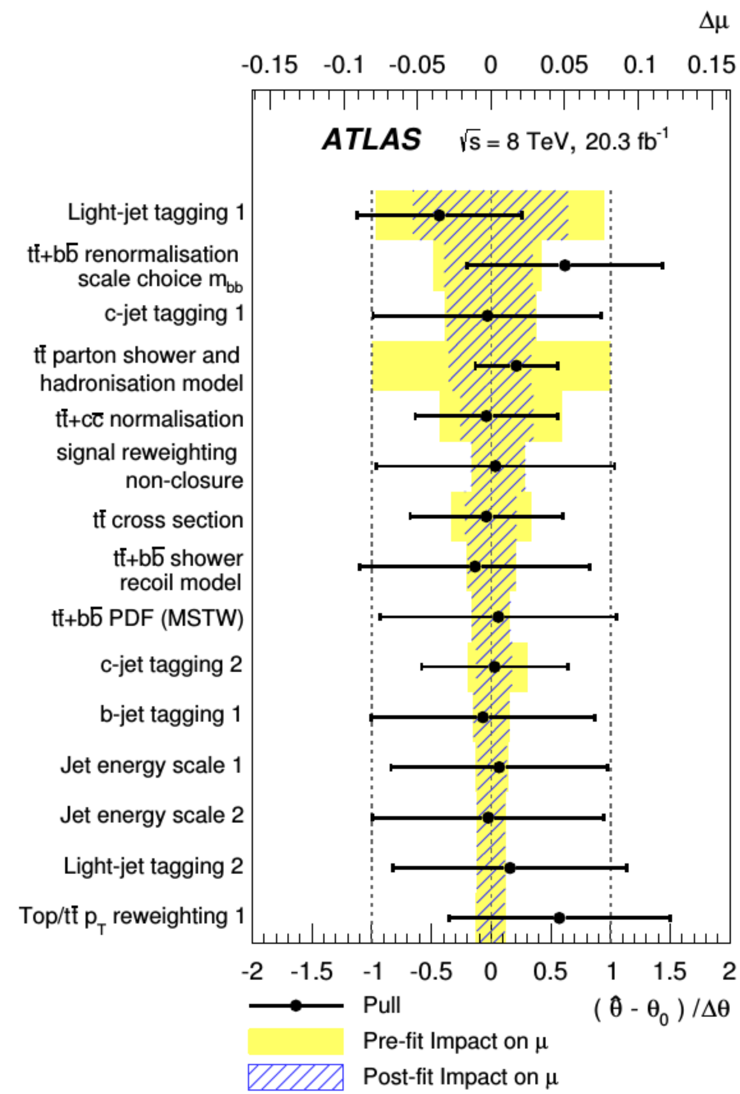
FCNC, $t \to Hq$ - ATLAS



FCNC, $t \to Hq$ - ATLAS

	Pre-fit				Post-fit			
	$WbHc$	$t\bar{t}$+LJ	$t\bar{t}+c\bar{c}$	$t\bar{t}+b\bar{b}$	$WbHc$	$t\bar{t}$+LJ	$t\bar{t}+c\bar{c}$	$t\bar{t}+b\bar{b}$
Luminosity	±2.8	±2.8	±2.8	±2.8	±2.6	±2.6	±2.6	±2.6
Lepton efficiencies	±1.5	±1.6	±1.6	±1.6	±1.5	±1.5	±1.4	±1.5
Jet energy scale	±3.4	±3.1	±2.4	±5.9	±1.4	±1.2	±1.8	±4.1
Jet efficiencies	±1.2	–	±1.9	±1.7	±0.9	–	±1.4	±1.2
Jet energy resolution	–	±1.2	±2.8	±2.9	–	–	±1.0	±1.1
b-tagging eff.	±7.9	±5.5	±5.2	±10	±5.7	±3.9	±3.7	±6.6
c-tagging eff.	±7.0	±6.6	±13	±3.6	±6.3	±6.0	±11	±3.2
Light-jet tagging eff.	±0.8	±18	±3.2	±1.6	±0.6	±13	±2.3	±1.1
$t\bar{t}$: reweighting	±5.9	±2.8	±4.3	–	±3.8	±1.9	±2.3	–
$t\bar{t}$: parton shower	±5.4	±4.8	±10	±4.9	±1.7	±1.5	±6.5	±3.1
$t\bar{t}$+HF: normalisation	–	–	±50	±50	–	–	±32	±16
$t\bar{t}$+HF: modelling	–	–	–	±7.7	–	–	–	±7.4
Signal modelling	±6.9	–	–	–	±6.8	–	–	–
Theor. cross sections	±6.2	±6.2	±6.2	±6.2	±3.9	±3.9	±3.9	±3.9
Total	±17	±22	±54	±53	±7.8	±14	±28	±15

Table 2: $t\bar{t} \to WbHc, H \to b\bar{b}$ search: summary of the systematic uncertainties considered in the (4 j, 4 b) channel and their impact (in %) on the normalisation of the signal and the main backgrounds, before and after the fit to data. The $t\bar{t} \to WbHc$ signal and the $t\bar{t}$+light-jets background are denoted by "$WbHc$" and "$t\bar{t}$+LJ" respectively. Only sources of systematic uncertainty resulting in a normalisation change of at least 0.5% are displayed. The total post-fit uncertainty can differ from the sum in quadrature of individual sources due to the anti-correlations between them resulting from the fit to the data.



Asymmetry in the boosted ljets channel - ATLAS

Table 2: The effect on the corrected charge asymmetry, in each $m_{t\bar{t}}$ interval, of systematic uncertainties on the signal and background modelling and the description of the detector response. The uncertainties are given in absolute percentages.

$m_{t\bar{t}}$ interval	> 0.75 TeV	$0.75 - 0.9$ TeV	$0.9 - 1.3$ TeV	> 1.3 TeV
Breakdown of detector-related systematic uncertainties				
Jet energy and resolution - $R = 0.4$ jets	0.1%	0.4%	0.2%	0.7%
Jet energy and resolution - $R = 1.0$ jets	0.3%	2.1%	0.4%	1.2%
b-tag/mis-tag efficiency	0.2%	0.3%	0.2%	0.4%
Lepton reco/id/scale	0.1%	0.2%	0.1%	0.2%
Missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$)	0.1%	0.1%	< 0.1%	0.1%
Background norm.	0.1%	0.1%	0.2%	0.5%
Combined detector-related uncertainties and others				
Stat. + detector-related syst.	2.0%	6.0%	4.0%	10.1%
Signal modelling - Matrix Element	1.5%	2.4%	0.6%	5.3%
Signal modelling - Parton Shower	2.0%	3.2%	1.2%	6.2%
Signal modelling - ISR/FSR	0.1%	0.3%	0.1%	3.0%
Unfolding & MC stat.	0.5%	1.2%	0.8%	2.1%
Total	3.2%	7.3%	4.3%	13.9%

Asymmetry with the template method - CMS

Table 2: Uncertainty in the combined measurement of A_c^y from systematic sources, ordered by decreasing magnitude.

(%)	Source of systematic uncertainty in A_c^y
0.18	Data sideband statistical uncertainty
0.15	Simulation statistical uncertainty
0.14	Jet energy scale
0.14	Renormalization and factorization scales
0.073	Modeling of b tagging
0.037	σ_{St} $(\sigma_{\mathrm{t}} + \sigma_{\bar{\mathrm{t}}})$
0.035	Jet energy resolution
0.026	Modeling of pileup
0.023	$\mathrm{Wb\bar{b}}$ content
0.021	Ratio of St cross sections, $\sigma_{\mathrm{t}}/\sigma_{\bar{\mathrm{t}}}$
0.021	Modeling of $\mathrm{t\bar{t}}$ production
0.018	PDFs
<0.010	$\mathcal{L}$, σ_{DY}, δ_{Wj}, trigger ϵ_μ, $F^{\mathrm{e}}_{\mathrm{Mj}}$, $\delta_{\mathrm{t\bar{t}}}$, α_s
<0.001	Trigger ϵ_{e}, $p_{\mathrm{T}}^{\mathrm{t}}$, $\mathrm{ID_e}$, ID_μ, F^{μ}_{Mj}
0.33	Total

Table 3: Results from the fit of the sample composition, in thousands of events, for the e+jets and μ+jets channels. The statistical uncertainty in the last digit is indicated in parentheses. The results of the simultaneous fit in both channels are included only for comparison and are not used in the measurement of A_c^y.

	Thousands of events						
	$\mathrm{t\bar{t}}$	Wj	Mj	St	DY	Total	Observed
e only	207.1(8)	49.1(9)	50(1)	14.0	5.4	326(2)	326.185
μ only	242.5(8)	58.9(6)	18.7(5)	16.5	4.3	341(1)	340.911
Simultaneous fit e	207.1(5)	49.5(4)	50.2(6)	14.0	5.4	326.2(9)	326.185
μ	242.6(6)	58.8(5)	18.7(5)	16.5	4.3	340.9(9)	340.911

Spin correlation and polarization - CMS

Variable	Data	MC@NLO	NLO+EW SM	NLO+EW uncorr.	f_{SM}
$A_{\Delta\phi}$	$0.094 \pm 0.005 \pm 0.012$	0.113 ± 0.001	0.110 ± 0.009	0.202 ± 0.009	1.18 ± 0.18
A_{c1c2}	$-0.069 \pm 0.013 \pm 0.016$	-0.081 ± 0.001	-0.080 ± 0.004	0	0.87 ± 0.27
$A_{\cos\varphi}$	$0.102 \pm 0.010 \pm 0.014$	0.114 ± 0.001	0.114 ± 0.006	0	0.90 ± 0.16
A_P	$-0.011 \pm 0.007 \pm 0.029$	0	0.002 ± 0.001	N/A	N/A
A_P^{CPV}	$-0.000 \pm 0.006 \pm 0.005$	0	0	N/A	N/A

Variable	Channel	Collaboration	f_{SM}
$\Delta\phi$	dilepton	ATLAS (8 TeV)	1.20 ± 0.14
ME-based (S-ratio)	dilepton	ATLAS (7 TeV)	0.87 ± 0.18 *
$\Delta\phi$	lepton+jets	ATLAS (7 TeV)	1.12 ± 0.25
$\Delta\phi$	dilepton	CMS (8 TeV)	1.16 ± 0.15
D	dilepton	CMS (8 TeV)	0.90 ± 0.16
ME-based	lepton+jets	CMS (8 TeV)	0.72 ± 0.17

J. Linacre, top 2015

Spin correlation and polarization - CMS

Asymmetry variable	$A_{\Delta\phi}$	A_P	A_P^{CPV}	A_{c1c2}	$A_{\cos\varphi}$
experimental systematic uncertainties					
Jet energy scale	0.002	0.019	0.001	0.007	0.009
Jet energy resolution	< 0.001	0.003	0.002	0.002	0.001
Lepton energy scale	< 0.001	0.003	0.002	0.006	0.002
b-tagging efficiency	< 0.001	0.001	0.001	0.001	0.001
Lepton selection	0.001	0.002	< 0.001	< 0.001	< 0.001
Pileup	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Background	0.001	0.002	< 0.001	0.001	0.001
$t\bar{t}$ modeling uncertainties					
Top quark mass	0.001	0.008	0.001	0.007	0.001
Fact. and renorm. scales	0.002	0.002	0.002	0.005	0.003
Parton distribution functions	0.004	0.001	< 0.001	0.005	0.005
Hadronization	0.001	0.019	0.003	0.005	0.004
Unfolding (simulation statistics)	0.002	0.003	0.003	0.006	0.005
Unfolding (regularization)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Top quark p_T	0.011	0.004	< 0.001	0.006	0.006

Pole mass from ttbar+1 jet events - ATLAS

Description	Value [GeV]	%
m_t^{pole}	**173.71**	
Statistical uncertainty	**1.50**	**0.9**
Scale variations	(+0.93, −0.44)	(+0.5, −0.3)
Proton PDF (theory) and α_s	0.21	0.1
Total theory systematic uncertainty	**(+0.95, −0.49)**	**(+0.5, −0.3)**
Jet energy scale (including b-jet energy scale)	0.94	0.5
Jet energy resolution	0.02	< 0.1
Jet reconstruction efficiency	0.05	< 0.1
b-tagging efficiency and mistag rate	0.17	0.1
Lepton uncertainties	0.07	< 0.1
Missing transverse momentum	0.02	0.1
MC statistics	0.13	< 0.1
Signal MC generator	0.28	0.2
Hadronization	0.33	0.2
ISR/FSR	0.72	0.4
Colour reconnection	0.14	< 0.1
Underlying event	0.25	0.1
Proton PDF (experimental)	0.54	0.3
Background	0.20	0.1
Total experimental systematic uncertainty	**1.44**	**0.8**
Total uncertainty	**(+2.29, −2.14)**	**(+1.3, −1.2)**

Pole-mass extraction - CMS

Source	Uncertainty [%]	
	7 TeV	8 TeV
Total (vis)	$\pm^{3.5}_{3.4}$	$\pm^{3.7}_{3.4}$
Q^2 scale (extrapol.)	$\pm^{0.4}_{0.0}$	$\pm^{0.2}_{0.1}$
ME/PS matching (extrapol.)	$\mp^{0.1}_{0.1}$	$\pm^{0.3}_{0.3}$
Top p_T (extrapol.)	$\pm^{0.4}_{0.2}$	$\pm^{0.8}_{0.4}$
PDF (extrapol.)	$\mp^{0.2}_{0.1}$	$\mp^{0.1}_{0.2}$
Total	$\pm^{3.6}_{3.4}$	$\pm^{3.8}_{3.5}$

Table 4: Individual contributions to the systematic uncertainty on the total $\mathrm{t\bar{t}}$ cross section measurements. The uncertainties are given in percentages. The total systematic uncertainties on the fiducial cross sections $\sigma_{\mathrm{t\bar{t}}}^{vis}$ are given in the row "Total (vis)" and those on the full phase space cross section $\sigma_{\mathrm{t\bar{t}}}$ in the row "Total".

Top mass from the b-jet energy spectrum - CMS

Table 2: Sources of systematic uncertainties and their contributions to the total uncertainty. The bJES estimated uncertainty covers uncertainties related to b-quark fragmentation.

Source of uncertainty	δE_{peak} (GeV)	δm_t (GeV)
Experimental uncertainties		
Jet energy scale	0.74	1.23
b jet energy scale	0.13	0.22
Jet energy resolution	0.18	0.30
Pile-up	0.02	0.03
b-tagging efficiency	0.12	0.20
Lepton efficiency	0.02	0.03
Fit calibration	0.14	0.24
Backgrounds	0.21	0.34
Modeling of hard scattering process		
Generator modeling	0.91	1.50
Renormalization and factorization scales	0.13	0.22
ME-PS matching threshold	0.24	0.39
Top p_T reweighting	0.91	1.50
PDFs	0.13	0.22
Modeling of non-perturbative QCD		
Underlying event	0.22	0.35
Color reconnection	0.38	0.62
Total	1.62	2.66

Color flow - ATLAS

Source	All particles [%]	Charged particles [%]
Unfolding procedure	0.5	0.6
Clusters	0.5	N/A
Tracks	N/A	0.2
JES	0.4	0.2
JER	0.3	0.1
Matrix element	1.5	0.9
Shower model	1.7	0.6
Colour model	1.3	1.0
ISR/FSR	1.2	0.2
MPI	0.1	0.6
Other	0.4	0.2
Total systematic uncertainty	3.0	1.8
Statistical uncertainty	1.1	0.7