Top quark physics with the ATLAS and CMS experiments

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On behalf of the ATLAS and CMS Collaborations

Moriond EWK

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La Thuile

The LHC has delivered $>10^6$ top quarks last year – what have we learnt?

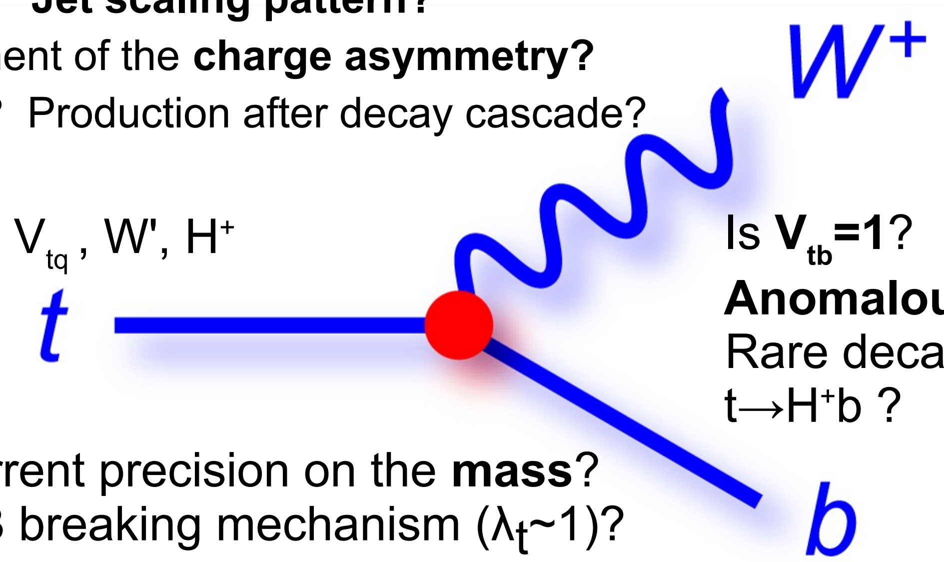
Top pair production: consistent with QCD prediction?

Spin correlations? **Jet scaling pattern?**

Differential measurement of the **charge asymmetry?**

Resonant production? Production after decay cascade?

Single top production: V_{tq}, W', H^+



Is $\mathbf{V_{tb}=1}$?

Anomalous couplings in Wtb vertex?

Rare decays by **FCNC** to γq, qZ, qg?

$t \to H^+ b$?

Can we improve the current precision on the **mass**?

Privileged role in EWSB breaking mechanism ($\lambda_t \sim 1$)?

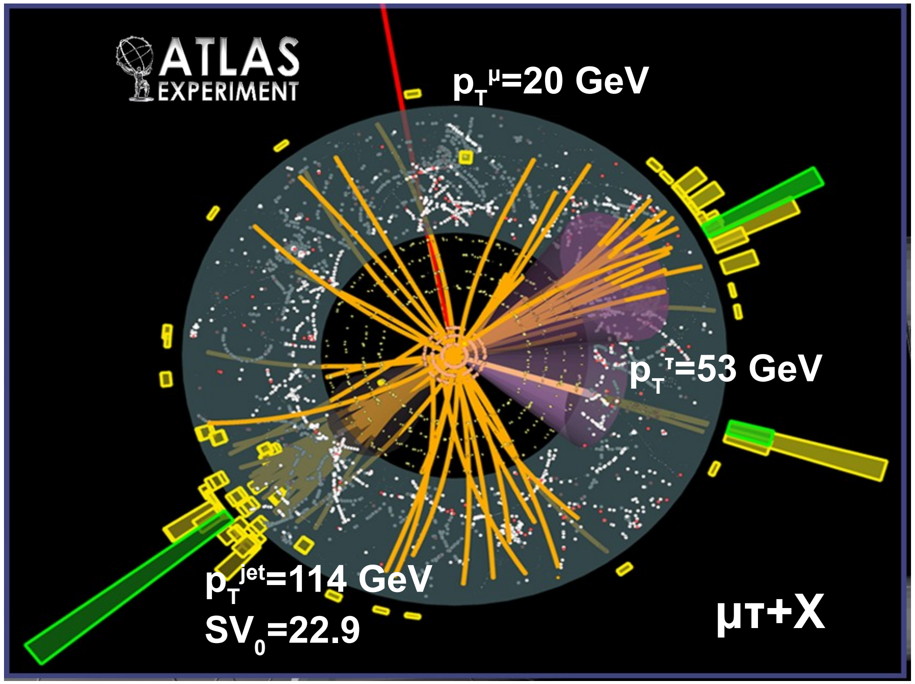
CPT invariance in the top sector: $m_{top} = m_{anti\text{-}top}$?

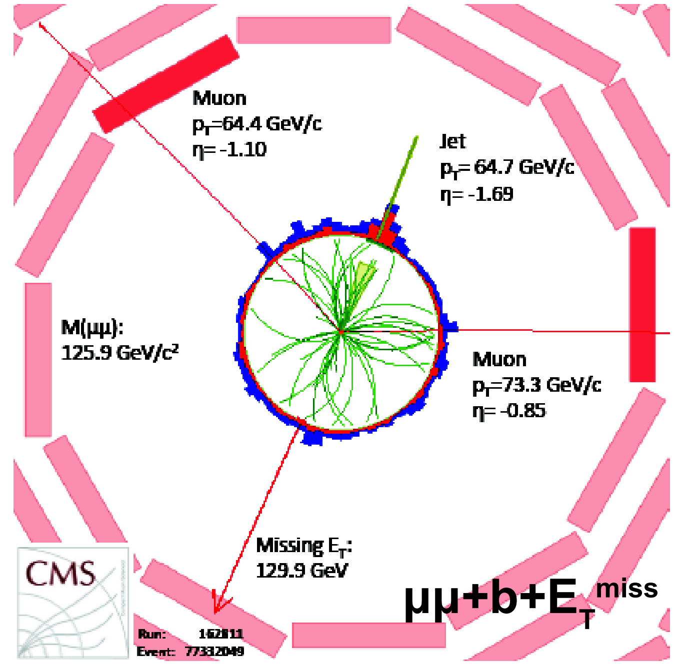
Is the **charge** of the decay products compatible with 2/3e?

Is the **width** of the prompt decay compatible with $\Gamma_t \sim 1.3$ GeV?

Many unknowns: unique sample for precision measurements and exploration of deviations from the SM at the LHC.

Selecting top quarks at the LHC

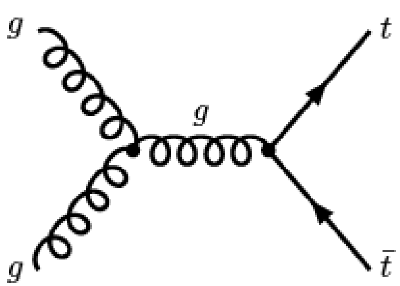


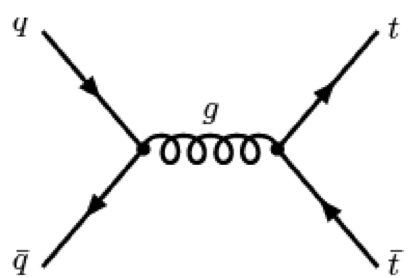


- **Trigger**
  - Single/double (isolated) leptons
  - and/or based on hadronic activity
- **Jets**
  - Anti-k_T algorithm with cone 0.4 or 0.5
  - p_T>20 GeV |η|<5 (analysis dependent)
  - b-tagging (optional)
- **Leptons (e,μ,τ) with p_T>20 |η|<2.5**
  - Isolation in tracker and calorimeters
  - Reconstruction quality, i.e. ID
    (number of hits, χ^2, conversion veto, etc.)
- **Missing transverse energy (E_T^{miss})**
  - Requirement is optional
  - Ranging from 20 to 60 GeV

Cross sections

Top pair production



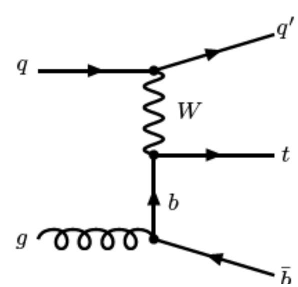


165^{+11}_{-16} pb

Aliev, M. et al
arXiv/hep-ph:1007.1327

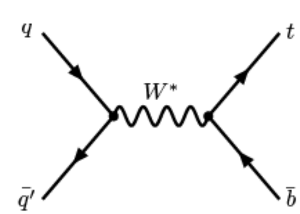
predictions... and measurements

Single top production



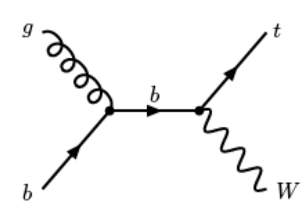
$64.57^{+2.09}_{-0.71}\ ^{+1.51}_{-1.74}$ pb

Kidonakis,N.
PRD83:091503,2011



$4.63 \pm 0.07^{+0.19}_{-0.17}$ pb

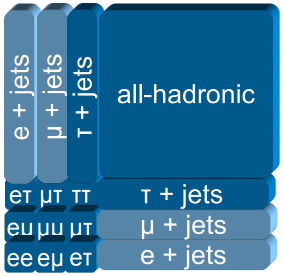
Kidonakis,N.
PRD81:054028,2010



$15.74 \pm 0.40^{+1.10}_{-1.14}$ pb

Kidonakis,N.
PRD82:054018,2010

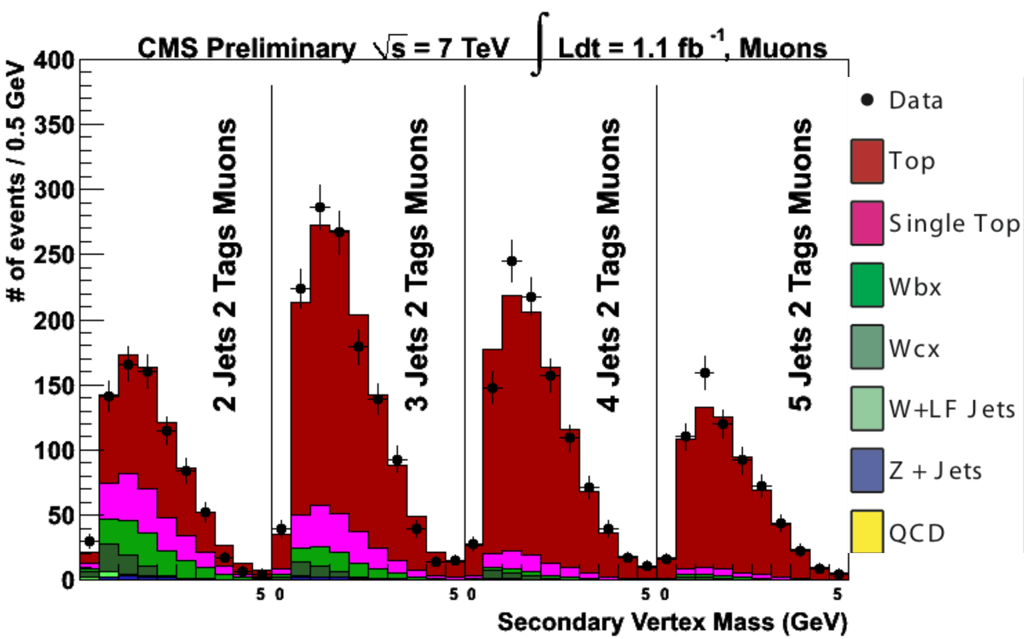
Lepton+jets channel

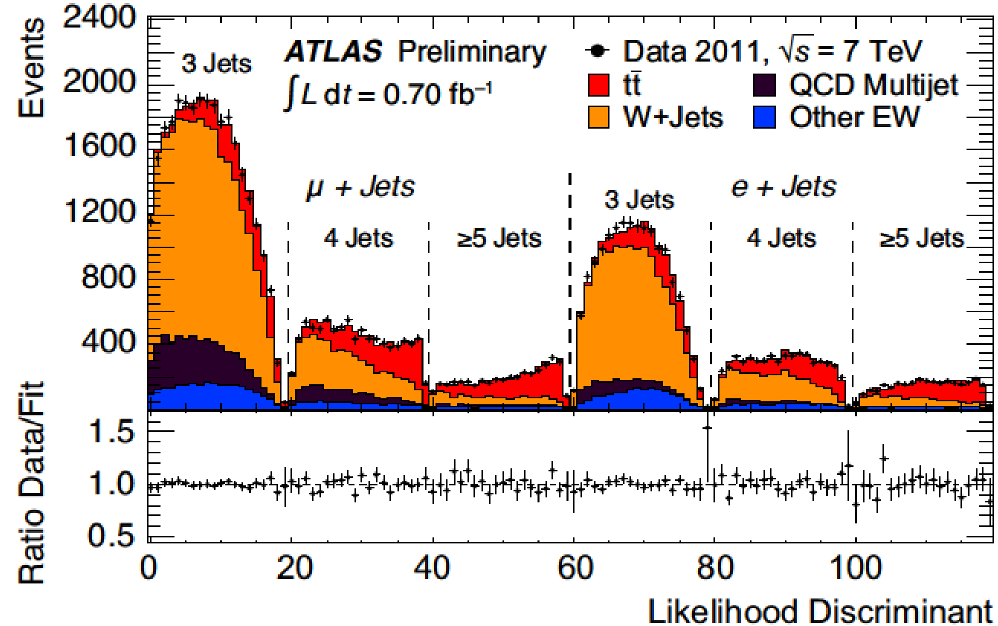


- Main backgrounds:
  - **QCD multijets** (rejected with m_T/MET, can be controlled from sidebands)
  - **W+jets** (in particular Heavy Flavor)
- **Use kinematics to discriminate top**

b-driven: mass of secondary vertex

topology driven: η_l, jet momentum tensor/H_T





▲ *More details on S.Khallil's talk @ YSForum*

- **Categorize events and extract σ_{tt} from fit**
  - W+HF normalization included in fit
  - Systematics treated as nuisance parameters (e.g. ISR/FSR, Q^2, b-tag efficiency)

Results

ATLAS

$$179.0 \pm 3.9(\mathrm{stat}) \pm 9.0(\mathrm{syst}) \pm 6.6(\mathrm{lumi})$$

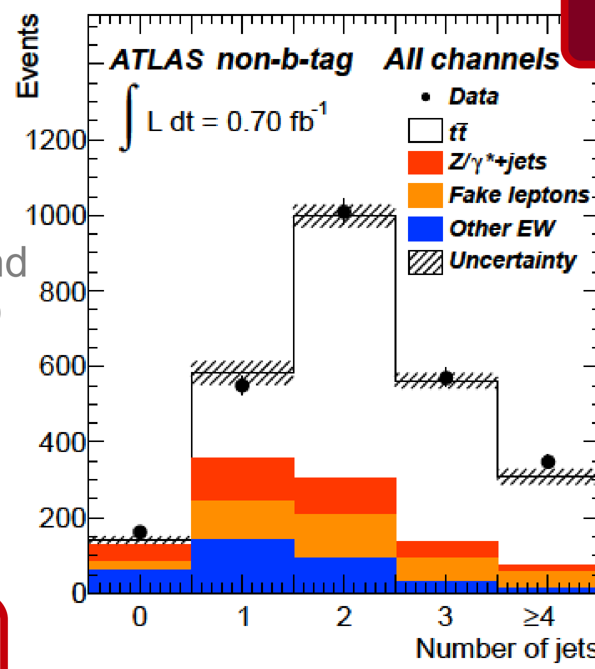
CMS

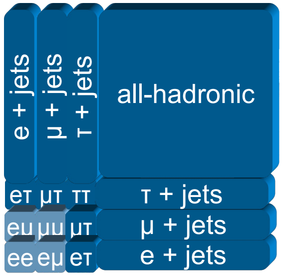
$$164.4 \pm 2.8(\mathrm{stat}) \pm 11.9(\mathrm{syst}) \pm 7.4(\mathrm{lumi})$$

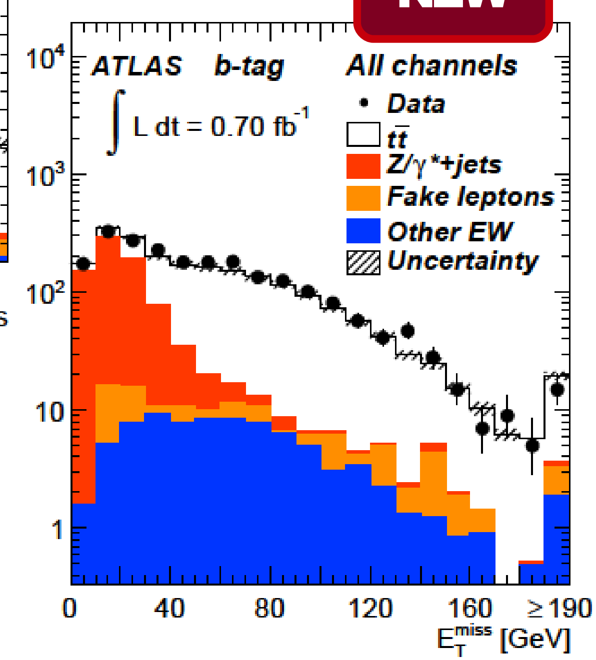
Dilepton channel

- **Cleanest signature**
- Main **backgrounds**:
  - **Drell-Yan** (Z-window is vetoed in ee/μμ and used to rescale DY contribution from data)
  - **Single top tW** and dibosons (from MC)
  - Residual **fake leptons** (controlled from sidebands using fake rate/efficiency)

"Signal is visible" even without requiring E_T^{miss} or b-tags







- **Main systematics**: jet energy scale, pileup (through E_T^{miss}), signal modeling, tW contribution
- Cross section measured from profile likelihood fit or from cut and count technique ►

Results

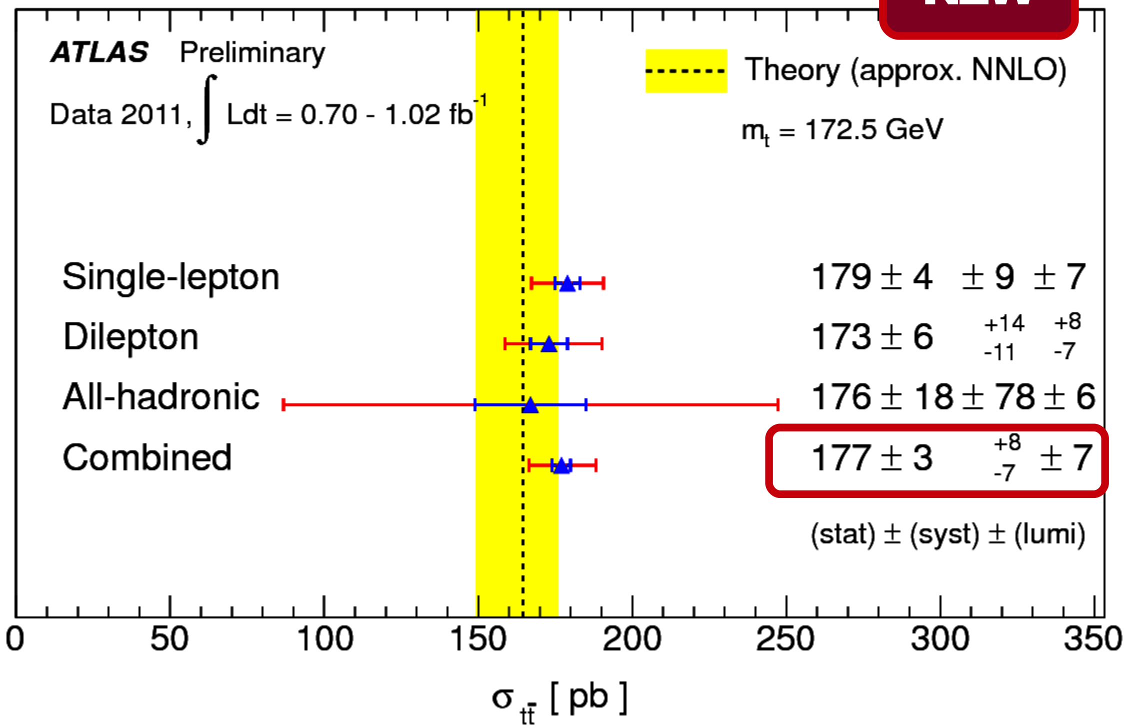
ATLAS $$176 \pm 5(\mathrm{stat})^{+14}_{-11}(\mathrm{syst}) \pm 8(\mathrm{lumi})$$

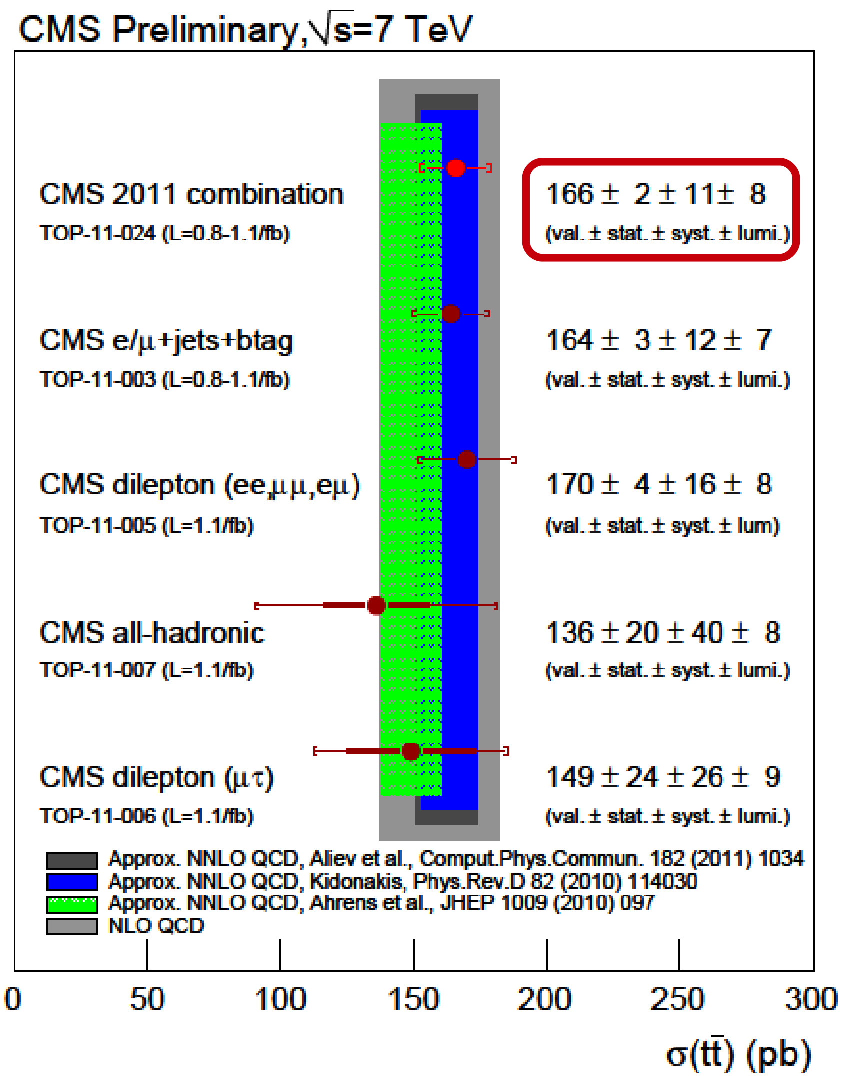
CMS $$169.9 \pm 3.9(\mathrm{stat}) \pm 16.3(\mathrm{syst}) \pm 7.6(\mathrm{lumi})$$

Combinations of the $t\bar{t}$ cross section at 7 TeV

ATLAS-CONF-2012-024 CMS PAS-TOP-11-024

NEW



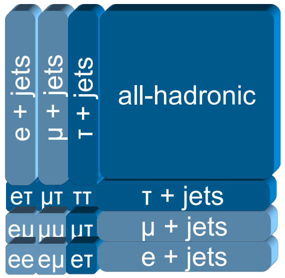


Excellent agreement between decay modes – starting to call for NNLO predictions.

- Total uncertainty: **Experimental: 6%**$_{ATLAS}$ – 8%$_{CMS}$ **Theory: 8%**$_{\text{approx. NNLO}}$

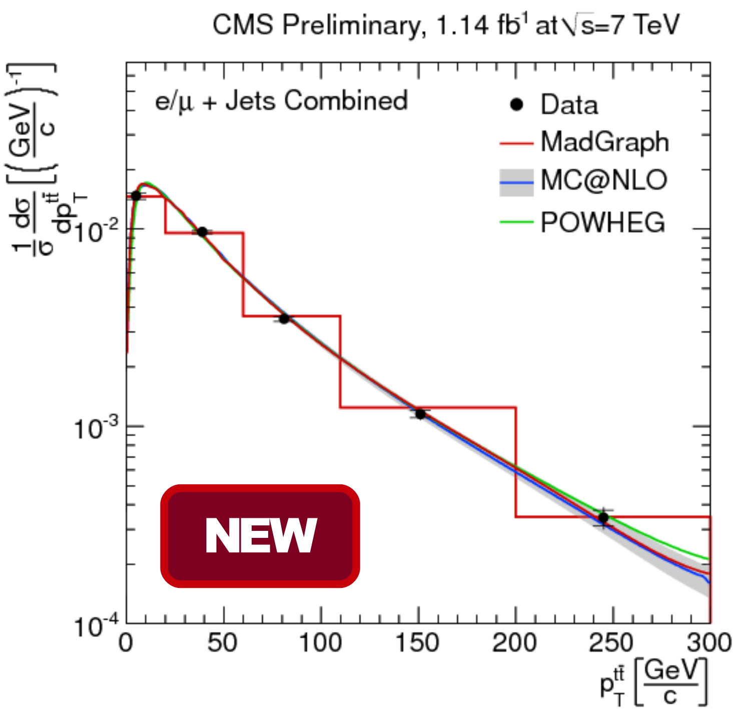
Testing pQCD - 1

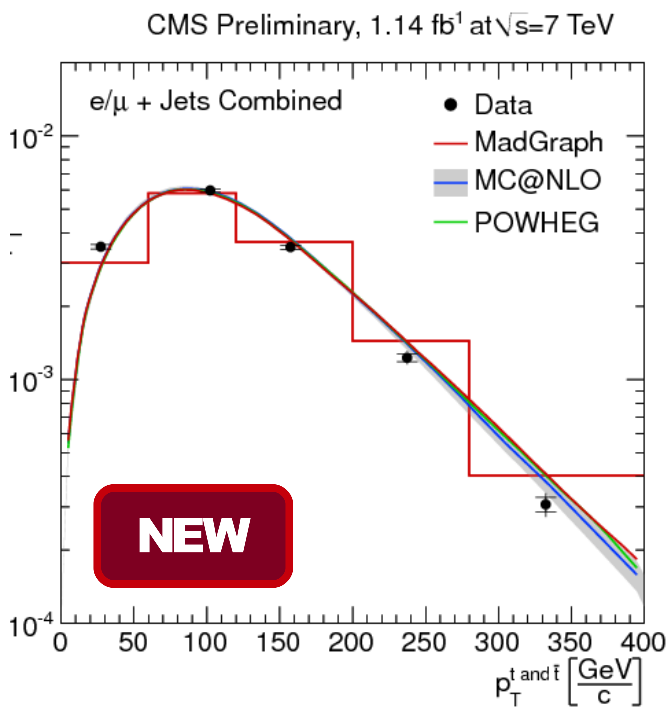
CMS-PAS-TOP-11-013

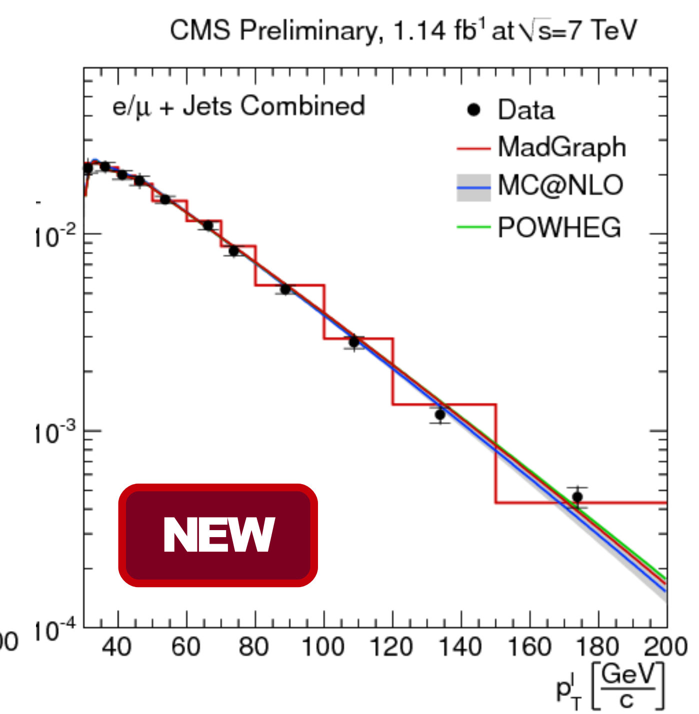


- Measurement of **differential cross-sections** $\boxed{\frac{1}{\sigma_{t\bar{t}}}\frac{d\sigma_{t\bar{t}}}{dX}}$
- Kinematics are reconstructed using different methods
  - after constrained fit (l+jets)
  - by prioritizing b-tagged jets and most probable neutrino energies for $100<m_t<300$ GeV/c^2 (dilepton)
  - Top pairs: p_T, η, M_{tt} Individual top quark: p_T, η Lepton kinematics: p_T, η, M_{ll}

Good agreement found for the different quantities in both dilepton and l+jets channels





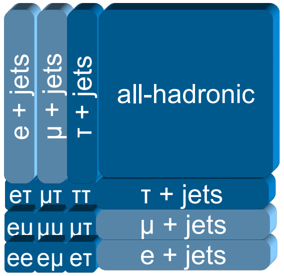


Testing pQCD - 2

ATLAS-CONF-2011-142

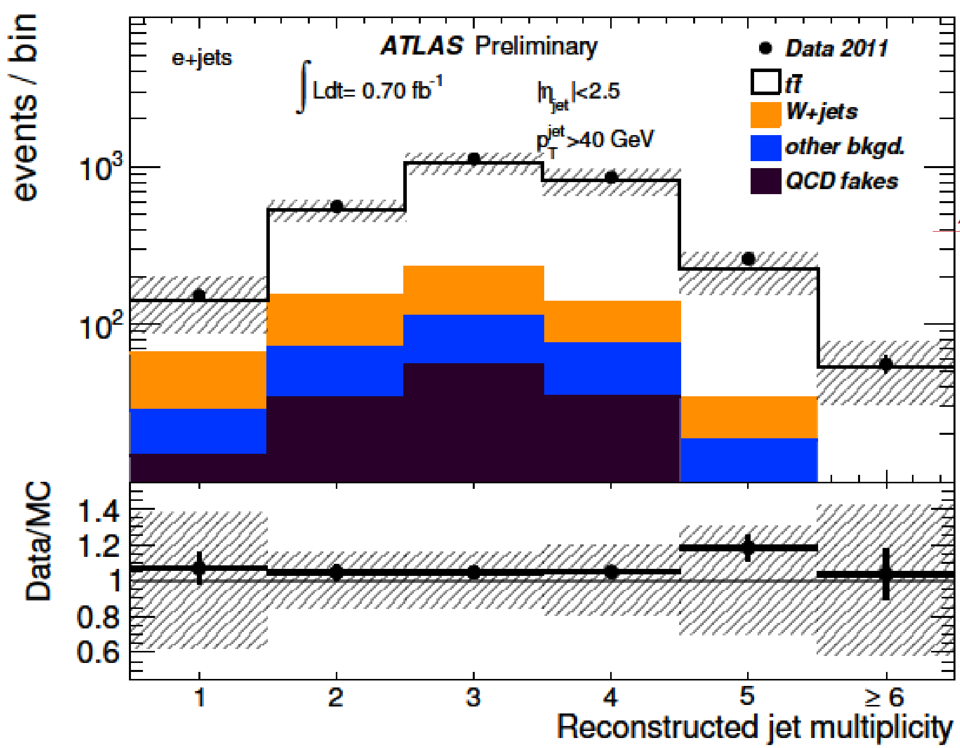
- **The jet scaling patterns** reflects QCD structure (PDF evolution and running α_s)
  - Crucial for many properties measurements affected by ISR/FSR contamination
  - Gauge central prediction with ISR variation in MC ►
  - Jet energy scale, W+QCD normalization and *b-tag efficiency* uncertainties dominate the measurement

▲ More details on A. Leyko's talk @ YSForum

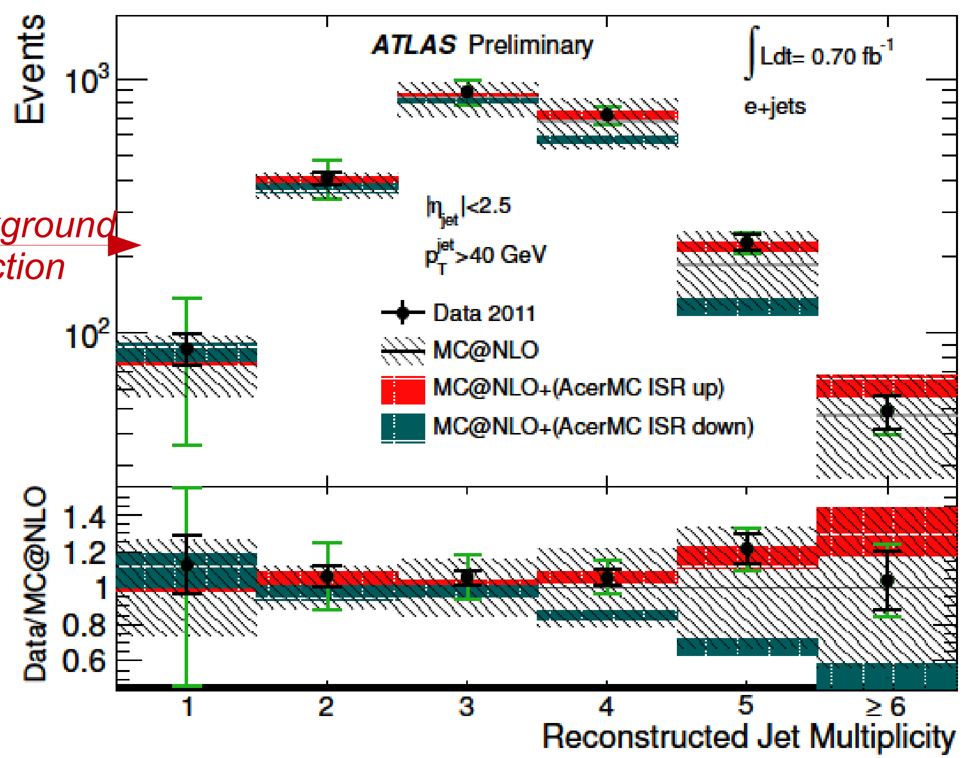


AcerMC sample	PARP(67)	PARP(64)
central	4	1
ISR down	1	4
ISR up	6	0.25

- **Overall good agreement** is found, but no distinction yet possible between different models

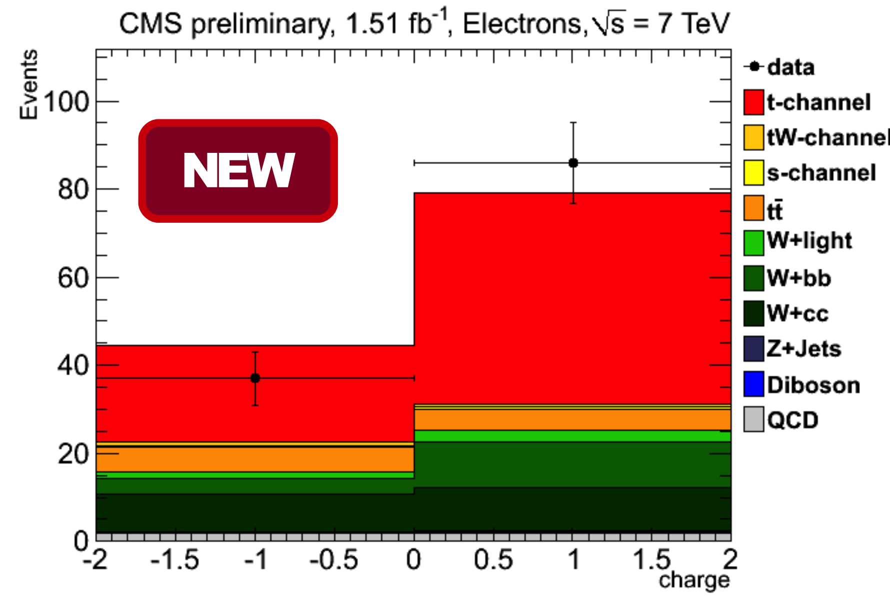


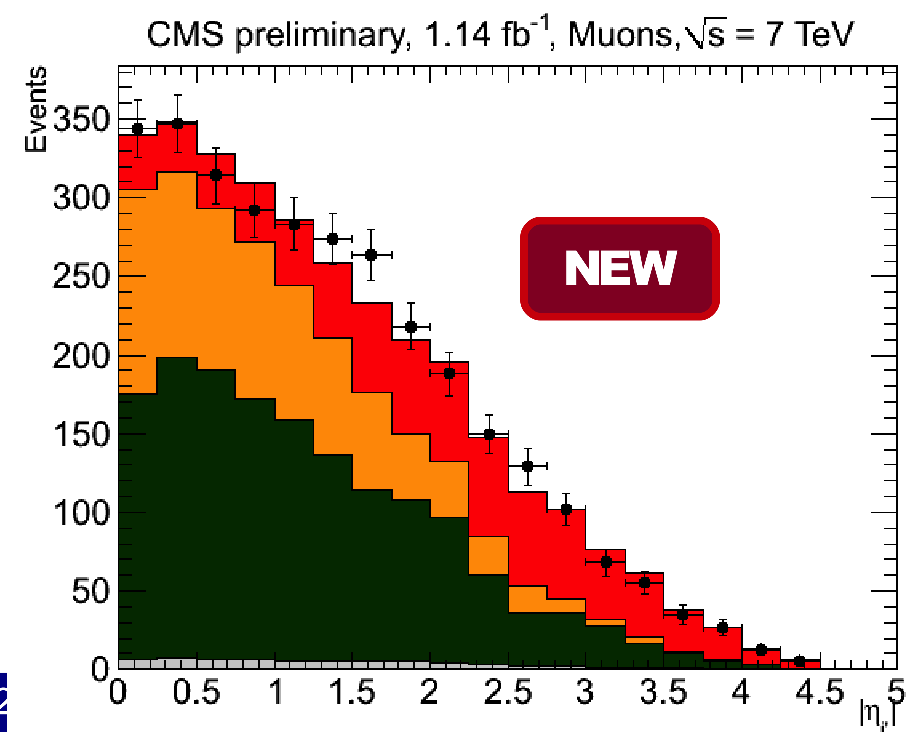
After background subtraction



Single top: t-channel

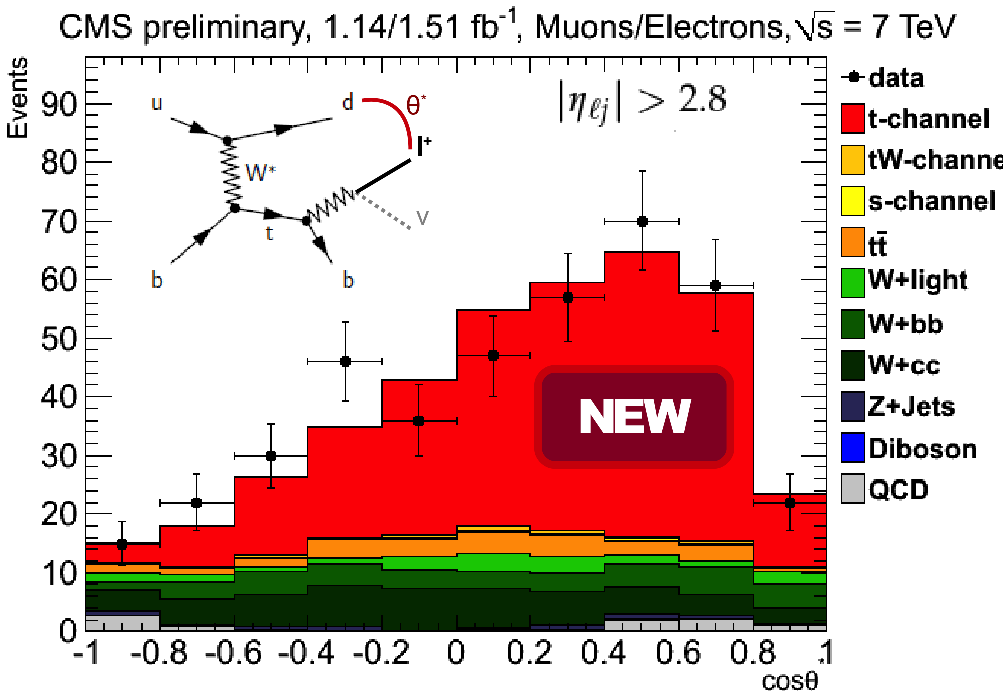
- **Dominant production channel**
  - **1 central, isolated lepton** + E_t^{miss}
    expect **$N(l^+) \approx 1.9\, N(l^-)$**, i.e. $N(t) \approx 1.9\, N(\text{anti-}t)$
  - 1 b jet + **1 forward recoil jet**
- Main backgrounds:
  - **Multijets**: fit to E_T^{miss}, or m_T spectrum with template from lepton selection side-band
  - **W+jets** (heavy flavor): fit from the discriminator output or re-scaled from selection sideband (e.g. failing $m_{l\nu b}$ requirement)
- Measurement stems from 2 cross-checks:
  - **fit to angular variables as** $\eta_{j'}$ – robust approach ►
  - multivariate analysis exploiting fully signal topology and maximizing significance (for CMS: not yet updated with 2011 data cf. CMS-PAS-TOP-10-008)

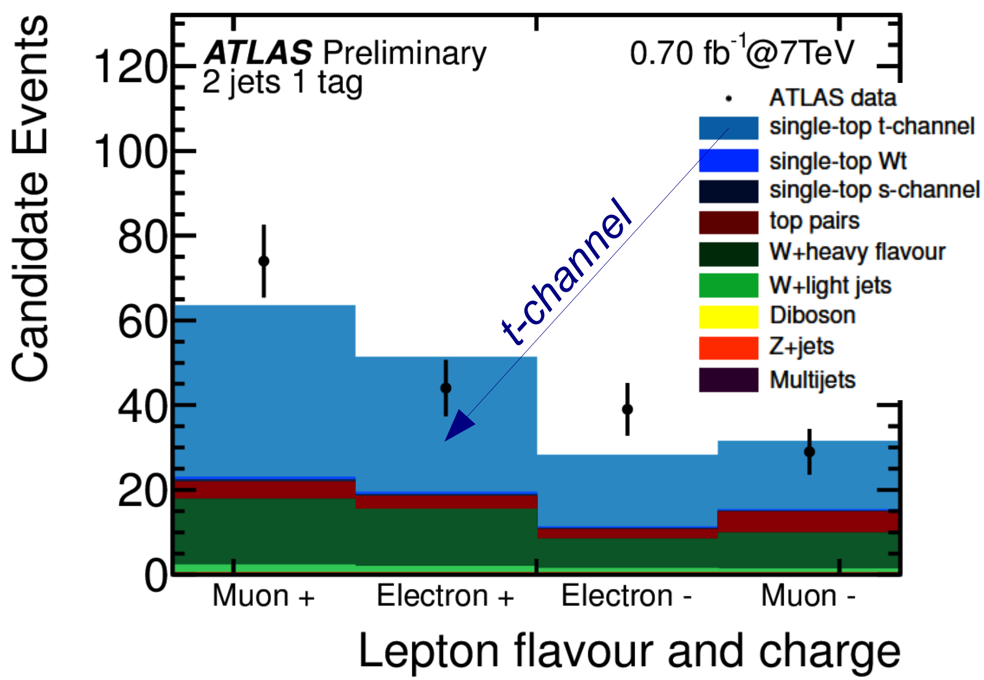




Single top: t-channel - results

ATLAS-CONF-2011-101 CMS- PAS-TOP-11-021





Results

CMS

$$70.2 \pm 5.2(\text{stat}) \pm 10.4(\text{syst}) \pm 3.4(\text{lumi})\ \text{pb}$$

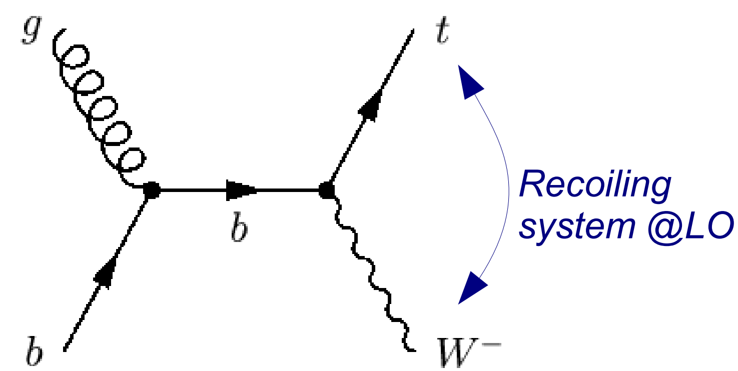
ATLAS

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

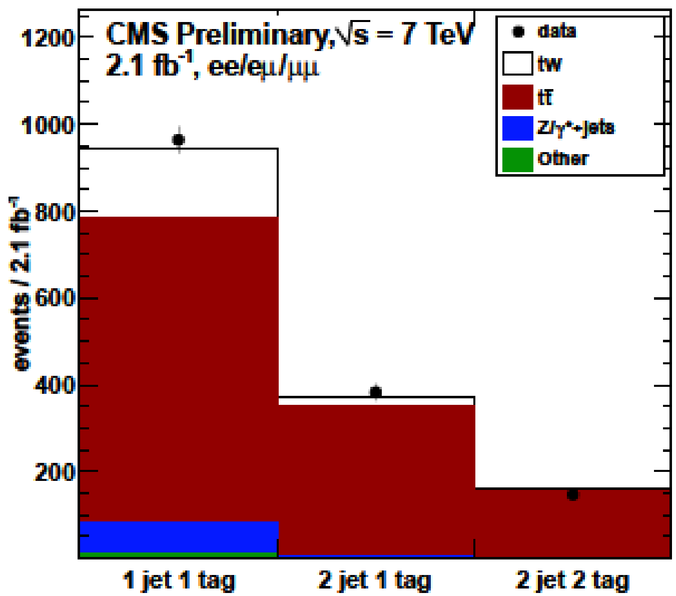
- **Leaving discovery phase: precision measurements just around the corner!**
  - Using expected th. cross section CMS obtains: $|V_{tb}| = 1.04 \pm 0.09(\text{exp}) \pm 0.02(\text{th})$
  - More to come: polarization, differential measurements

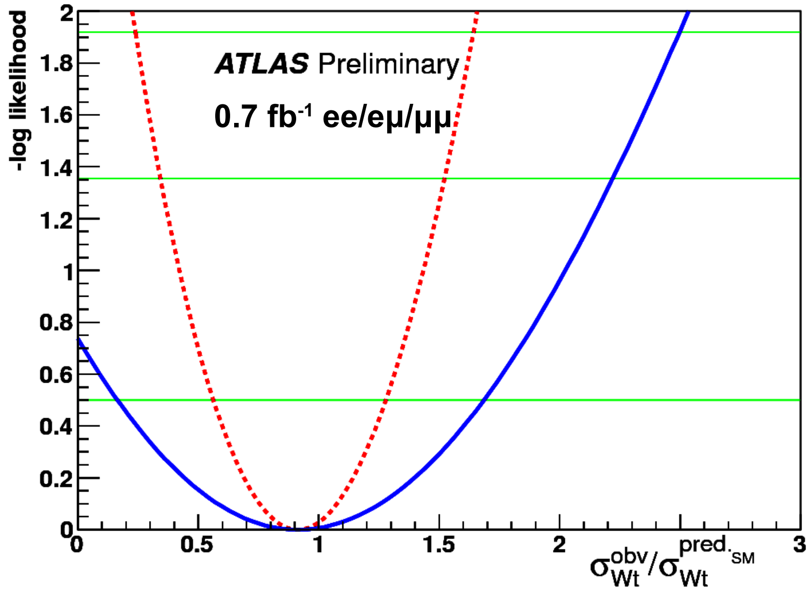
Single top: tW-channels

- **Final state: 2 leptons+1 b-jet+E_T^{miss}** (at LO similar to tt dileptons with only 1 b-jet)
- Signal discrimination
  - 2nd b-jet veto is applied for signal region
  - **Balance:** $|\sum_{leptons} \vec{p}_T + \vec{p}_T^{\,b-jet} + \vec{E}_T^{miss}| < 60\ GeV$ ▶
  - Categorize events to constrain tt and ε_b



- Use **max. likelihood fit for σ(tW):**





Results

CMS

$$22^{+9}_{-7}(\text{stat} \oplus \text{syst})\ \text{pb}$$

(significance=2.7σ)

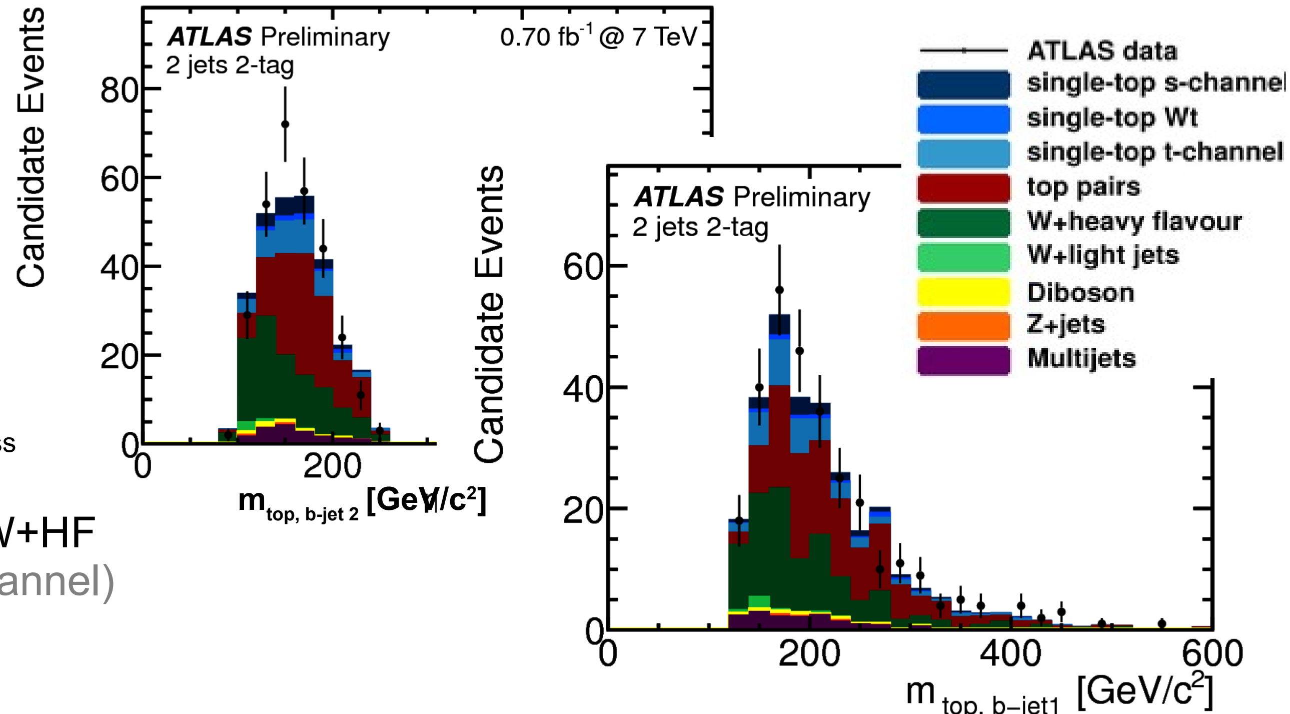
ATLAS

$$14.4^{+5.3}_{-5.1}(\text{stat})^{+9.7}_{-9.4}(\text{syst})\ \text{pb}$$

(significance=1.2σ)

On the road to establish the s-channel

More details on M. zur Nedden's talk

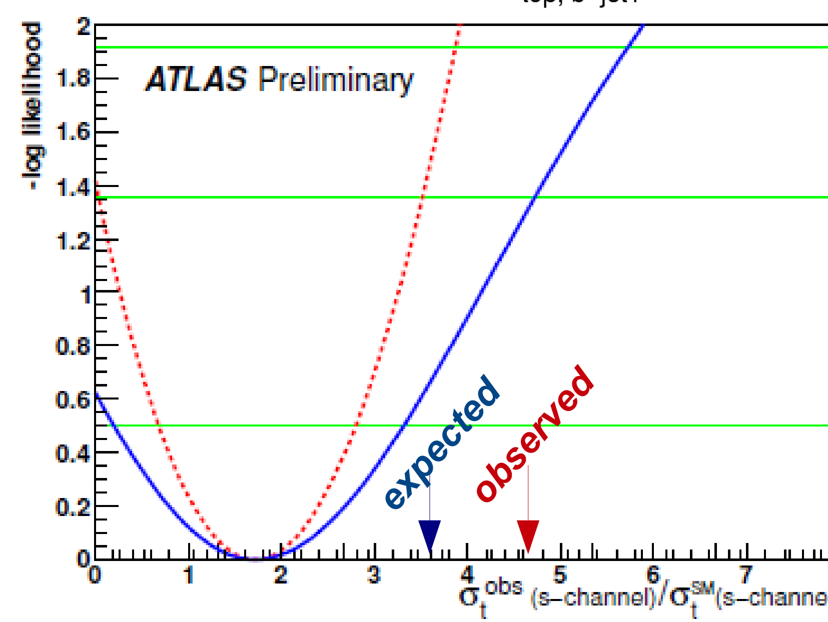


- **Lowest cross section, may reveal new physics:**
  - W' , massive $H^{\pm} \rightarrow t + b$
- Signature: 1 lepton+2 b-jets+E_T^{miss}
  - Contaminated by QCD multijets, W+HF and top pair events (similar to t-channel)
- **Categorize according to b-tag multiplicity and analyze kinematics**
  - Jet kinematics, invariant mass of objects, etc.
  - Apply sequential cuts maximizing $S/B^{1/2}$
  - Exp. S/B=16/296 → interpret statistically

Results

ATLAS

$$< 26.5 \text{ pb } (20.5 \text{ pb exp.}) \ @ \ 95\%\text{CL}$$



Properties

We have selected the top at the LHC

and we can measure its properties at production and decay.

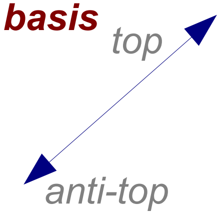
Evidence for spin correlations

ATLAS-CONF-2011-117

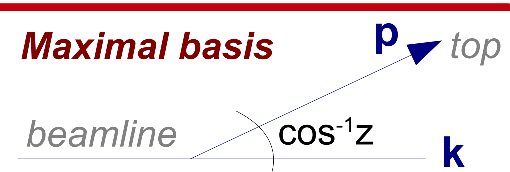
- **Top decays promptly→spin information is conserved**
- Spin correlation can be sought after full kinematics reconstruction measuring:

$$A = \frac{\sigma_{tt}(\uparrow\uparrow)+\sigma_{tt}(\downarrow\downarrow)-\sigma_{tt}(\uparrow\downarrow)-\sigma_{tt}(\uparrow\downarrow)}{\sigma_{tt}(\uparrow\uparrow)+\sigma_{tt}(\downarrow\downarrow)+\sigma_{tt}(\uparrow\downarrow)+\sigma_{tt}(\uparrow\downarrow)}$$

Helicity basis

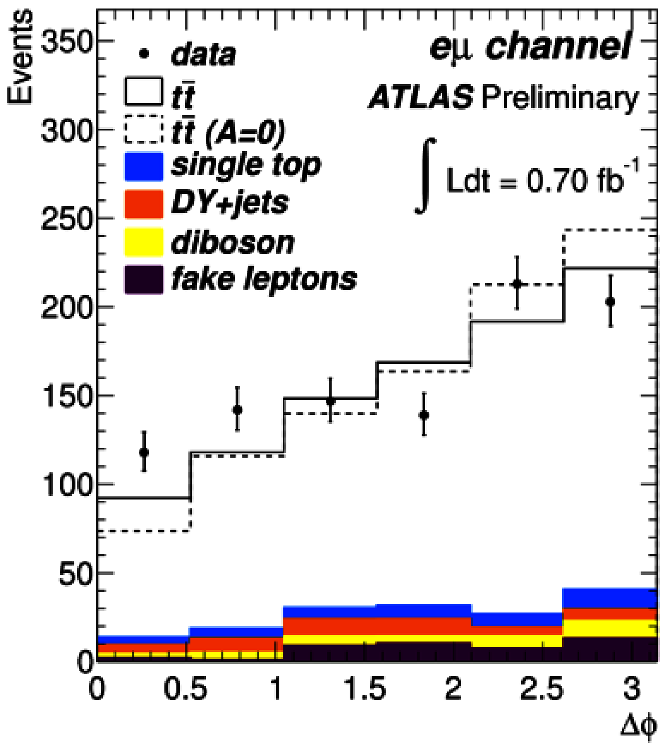


Maximal basis



$$\mathbf{e}_{+}^{q} \sim \frac{\mathbf{p}+(\gamma-1)z\hat{\mathbf{k}}}{\sqrt{1+z^2(\gamma^2-1)}}$$

- Most interesting probes: leptons or d-type quarks
  - carry most of the top-spin information
- **Strategy followed: fit *Δφ* distribution** with binned templates for SM and uncorrelated cases ►
  - Translate result to maximal/helicity basis: $A_{basis} = f \cdot A_{basis}^{SM}$
  - Main systematics: ISR/FSR and signal modeling
- **Evidence for spin correlations in agreement with SM**



◄ *SM prediction computed with MC@NLO and CTEQ6.6 PDF*

Results

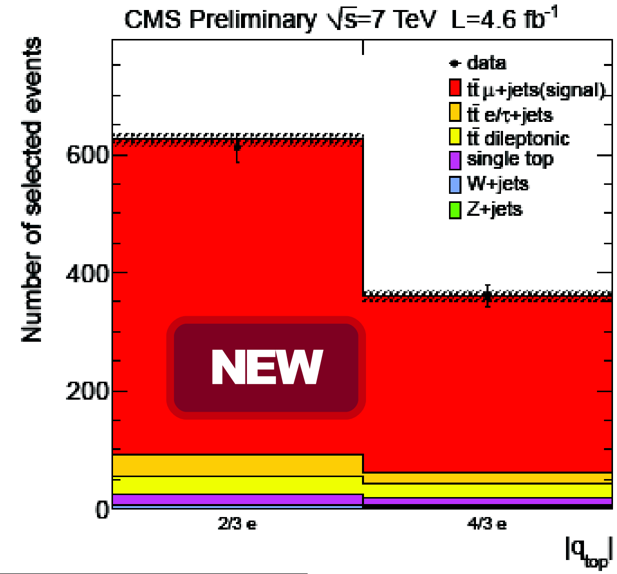
ATLAS

$$A_{\rm helicity} = 0.34 \pm 0.07_{\rm stat}\ {}^{+0.13}_{-0.09}\ {\rm syst} \qquad A^{\rm SM}_{\rm helicity} = 0.32$$

$$A_{\rm maximal} = 0.47 \pm 0.09_{\rm stat}\ {}^{+0.18}_{-0.12}\ {\rm syst} \qquad A^{\rm SM}_{\rm maximal} = 0.44$$

Top quark charge
directly reflected in decay products

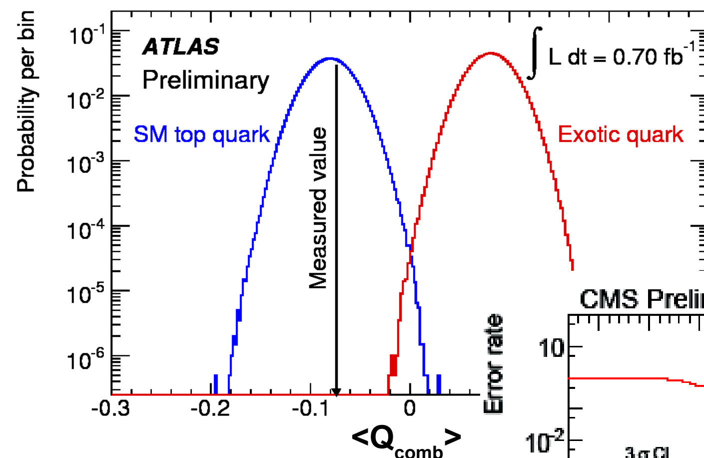
- **Assign charge from semi-leptonic b decays**
  - Minimize wrong charge assignment (e.g. B→D, B_0 oscill.)
  - p_T^{rel} is used to optimize efficiency and dilution: $D=\frac{N_{correct}-N_{wrong}}{N_{correct}+N_{wrong}}$
  - Performance measured in QCD bb events

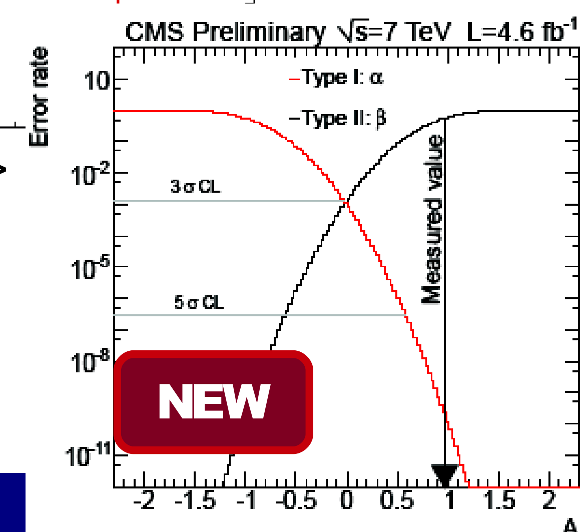


- Limit exotic scenario from **asymmetry in charge categories**

$$A = \frac{1}{D_S}\frac{N_{SM}-N_{XM}-<N_{BG}>D_B}{N_{SM}+N_{XM}-<N_{BG}>}$$

  - N_{SM} and N_{XM} are described by prob. functions using signal/bckg
  - CMS measures:
    $$A_{meas} = 0.97 \pm 0.12_{stat} \pm 0.31_{syst}$$
  - Quantify from pseudo-experiments the probability to make type I/II errors ▶



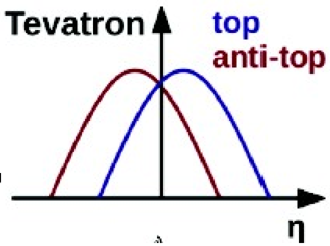


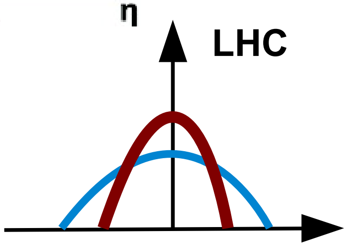
Both experiments exclude exotic scenarios at >5σ

Top charge asymmetry

- **Tevatron observes a differential dependency on the charge asymmetry** cf. arXiv:1101.0034 arXiv:0712.0851
  - Sign of new physics? Confirmed by other experiments?
- **Crucial difference at the LHC: we collide mainly gluons**
  - Intrinsic SM asymmetry is highly diluted $A_C^y(\text{theory}) = 0.0115 \pm 0.0006$
  - Anti-quarks from sea tend to have lower x
  - At the LHC define asymmetry defined as $A_C = \frac{N^+ - N^-}{N^+ + N^-}$

    $N^{\pm}$ is the number of events with $\pm\, \Delta y = |y_{top}| - |y_{anti\text{-}top}|$





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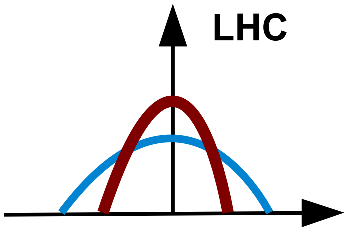
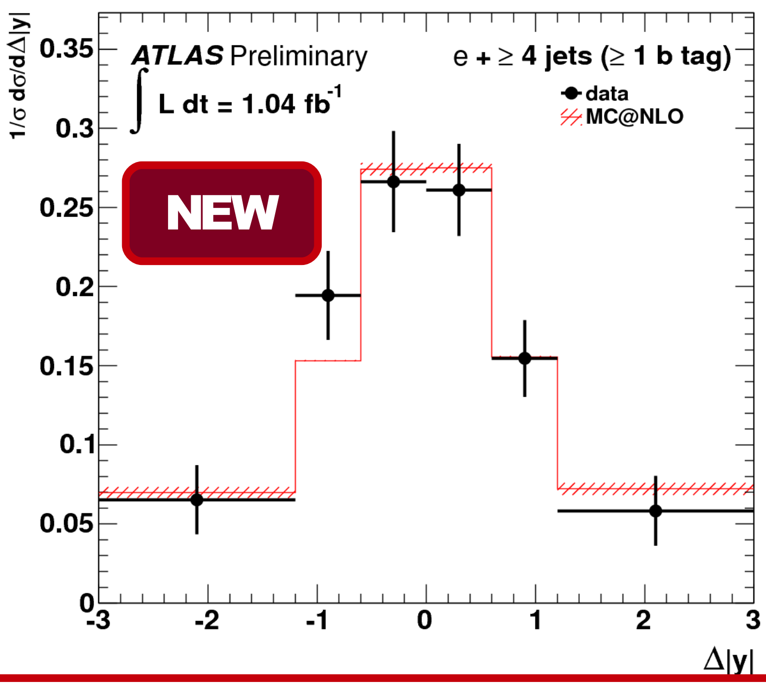
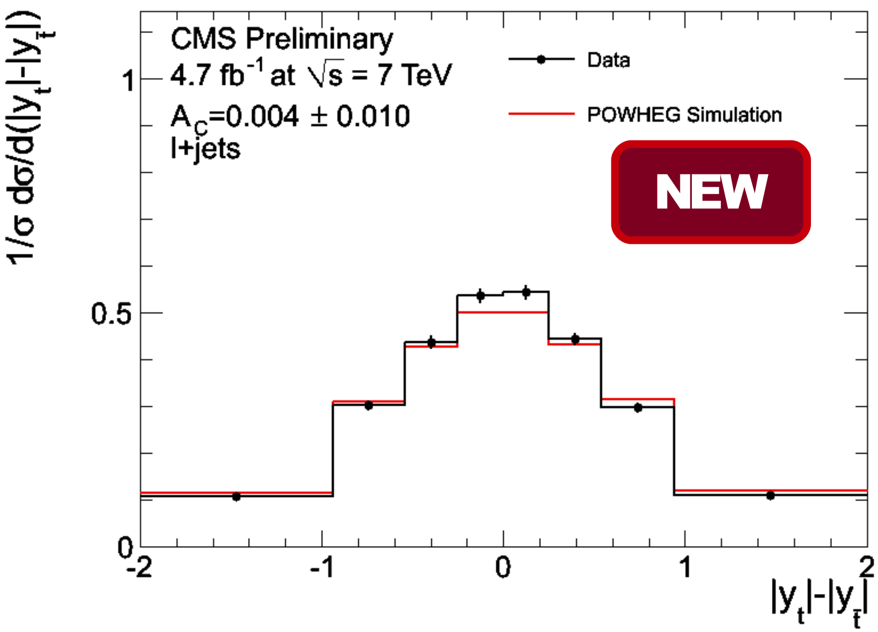






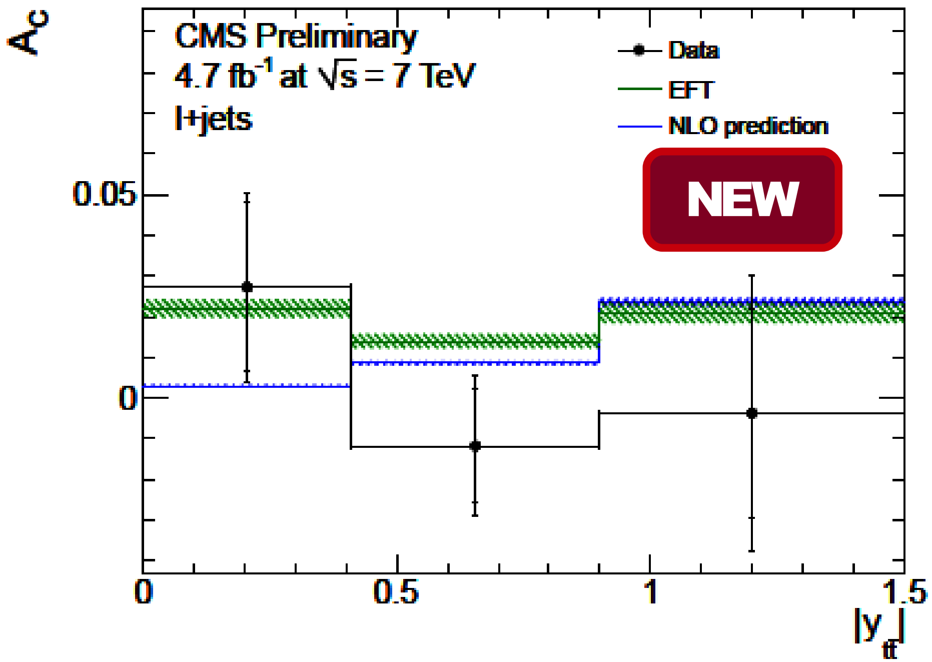
Results

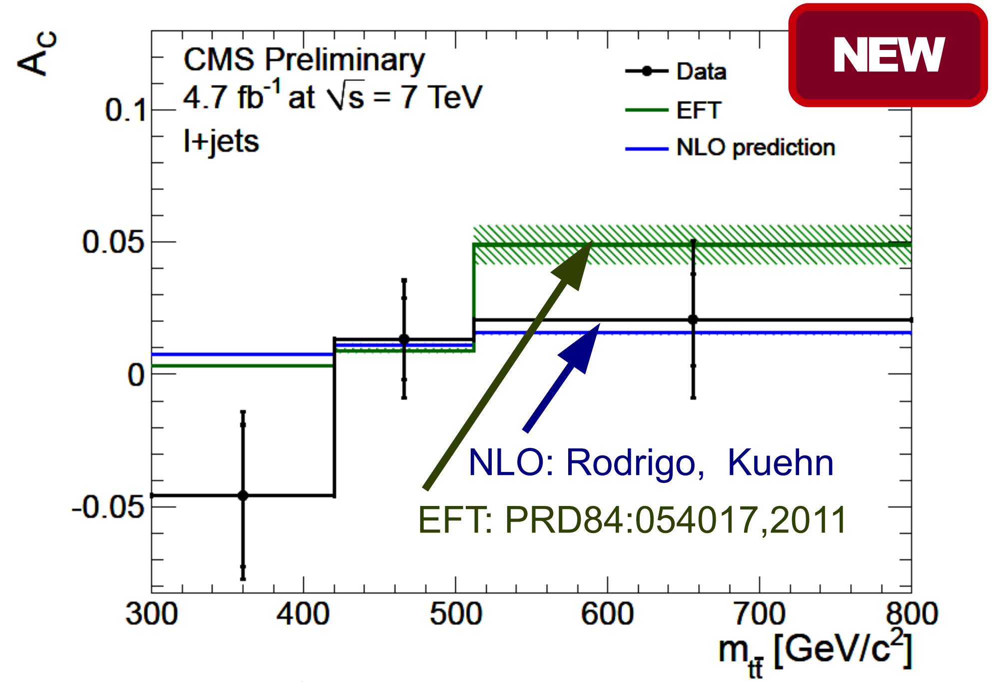
ATLAS $-0.018 \pm 0.028_{\text{stat}} \pm 0.023_{\text{syst}}$

CMS $0.004 \pm 0.010_{\text{stat}} \pm 0.012_{\text{syst}}$

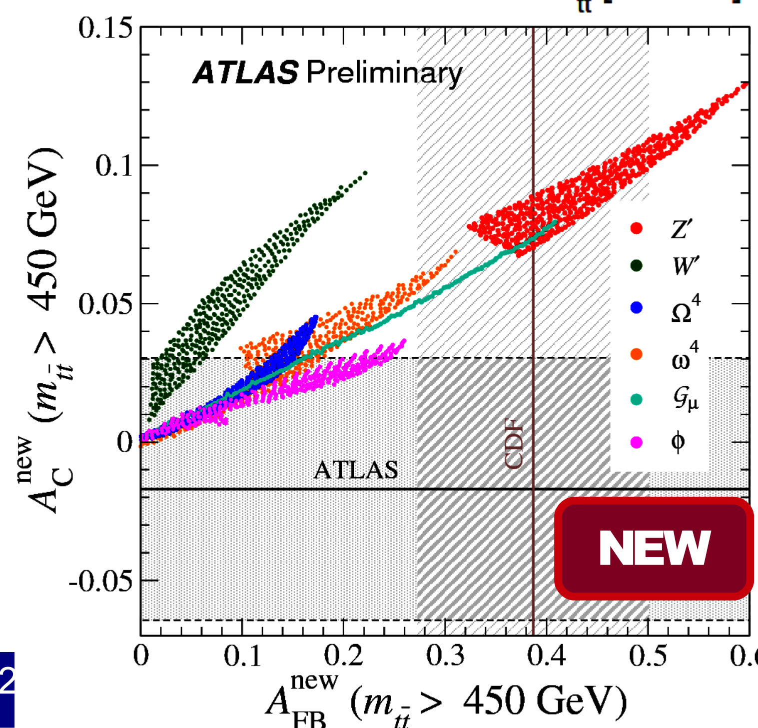
Differential top charge asymmetry

ATLAS-CONF-2011-106+updates CMS-PAS-TOP-11-30





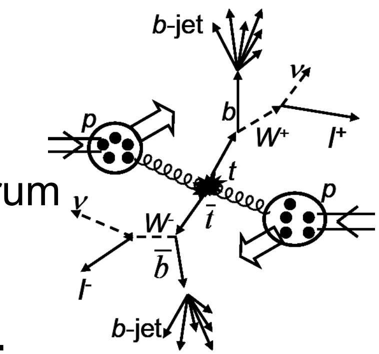
- Asymmetry measured in p_T, y or invariant mass of the top pair system
- **Good agreement found between data and SM expectations within uncertainties**
- Dependence on invariant mass reported by both experiments and compared to BSM models or Eff. Field Th. prediction (anomalous axial coupling of gluons to quarks)



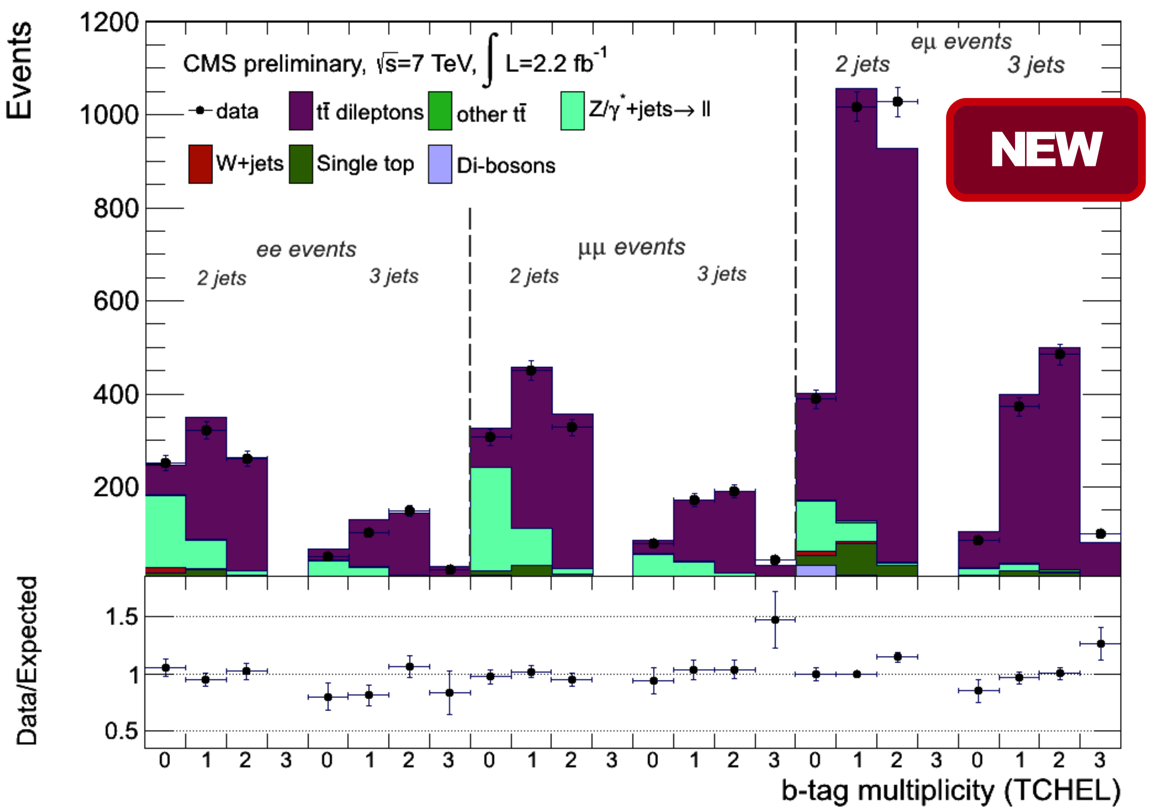
- Some tension between SM and D0 measurement: $R_{\text{dileptons}} = 0.86 \pm 0.05\ (\text{stat} \oplus \text{syst})$

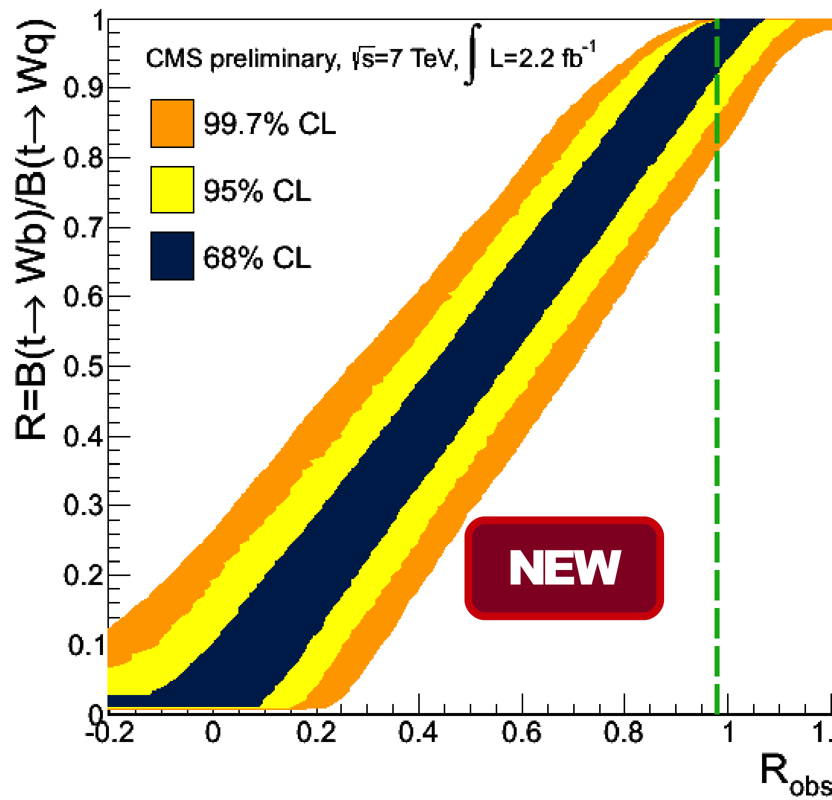
cf. PRL107:121802,2011

- **Measurement is fully data-driven**
  - b-tagging multiplicity is parametrized as function of R, ε_b, ε_q, top contributions
  - number of reconstructed t → Wq is estimated from lepton-jet invariant mass spectrum



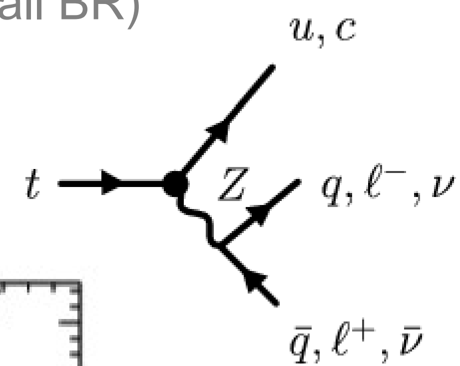
- $\boxed{R = 0.98 \pm 0.04\ (\text{stat} \oplus \text{syst})}$
  - lower endpoint of the confidence interval @ 95% CL after requiring R<1 is **R>0.85**

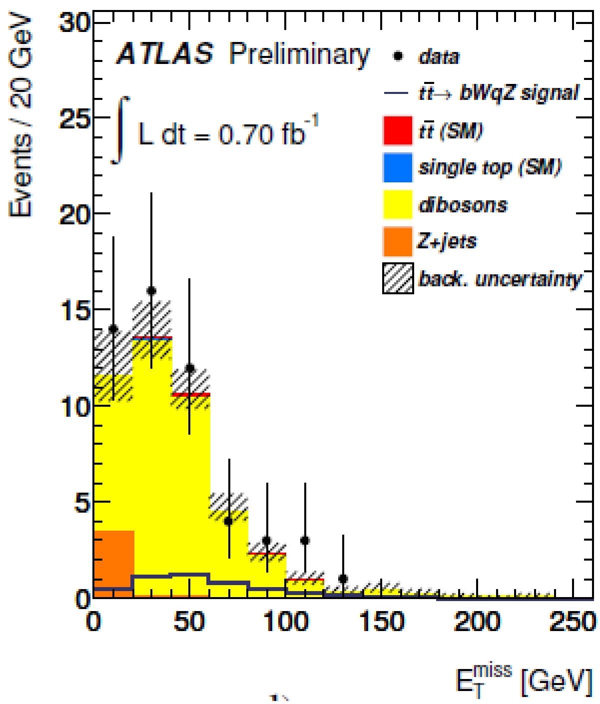


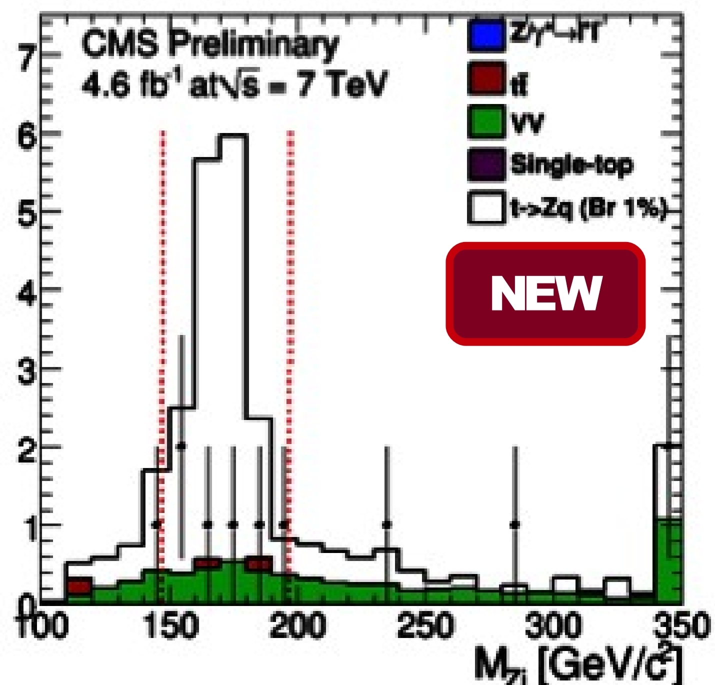


Rare decays : FCNC

- At **LO FCNC is highly suppressed**: $BR_{SM}(t \rightarrow qZ) \sim 10^{-14}$
  - NLO corrections from **BSM scenarios can enhance** the BR **by almost a factor of 10^{10}**
- **Search in top decays: $t \rightarrow qZ \rightarrow q\, l^+l^-$** (trilepton events, clean but small BR)
- After pre-selection assign top decays from min χ^2 or requiring 1 b-tag
  - Full kinematics specified from χ^2 fit or using m_W and E_T^{miss} constraints







Results ATLAS $BR(t \rightarrow qZ) < 1.3\%$ CMS $BR(t \rightarrow qZ) < 0.34\%$

Search for FCNC in single top

More details on M. zur Nedden's talk

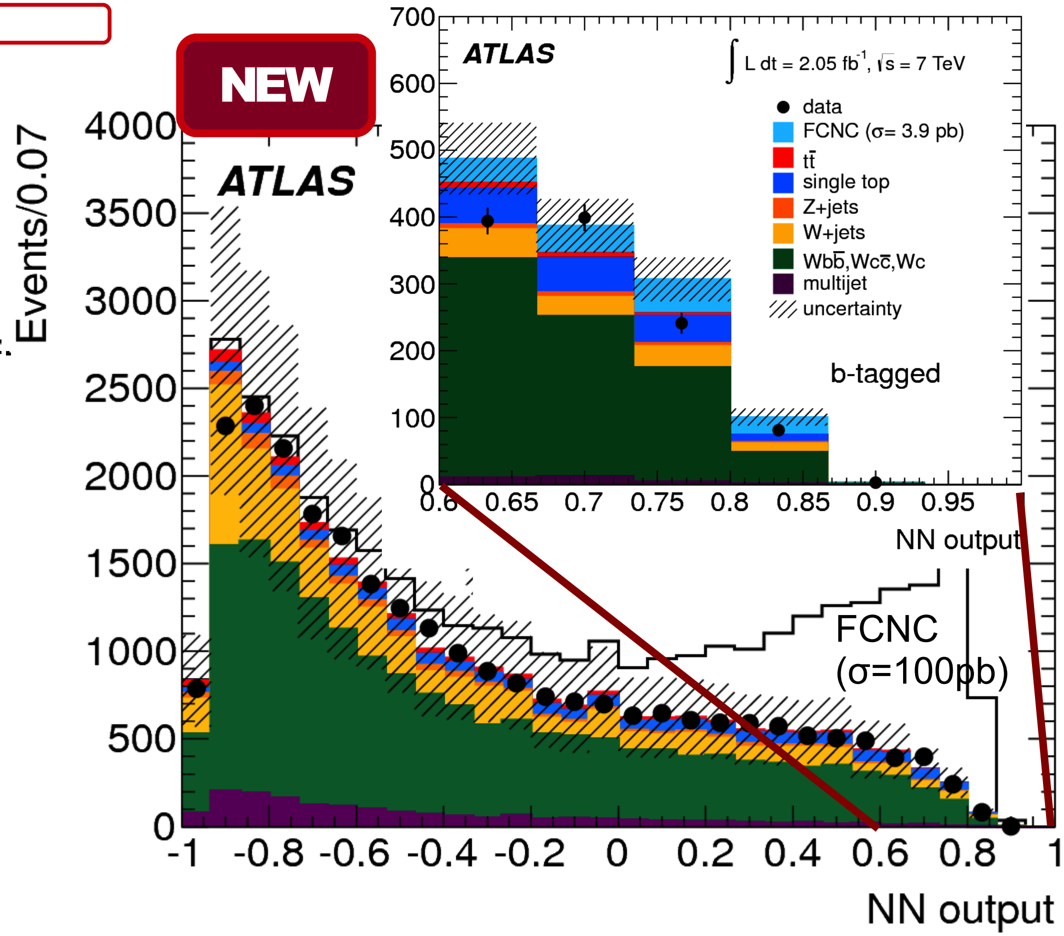
- Single top production can be **enhanced through 6-dim tensor coupling**:

$$\mathcal{L}_{\text{eff}} = g_s \sum_{q=u,c} \frac{\kappa_{qgt}}{\Lambda} t\, \sigma^{\mu\nu} T^a \left(f_q^L P_L + f_q^R P_R \right) q G^a_{\mu\nu} + \text{h.c.}$$

Effective coupling (κ_{qgt}); NP scale (Λ); Norm. chiral parameters (f_q^L, f_q^R)

- Search for: $qg \to t \to W(\to \ell\nu)b$
  - $m_T + E_T^{miss} > 60$ GeV
  - Require only 1 jet (b-tagged)
  - ~55 evts/fb selectable (for $\sigma_{qg\to t}$=1 pb)
- **Expect top to be mostly at rest, top/anti-top ~ 4/1, largely boosted W**
  - use topology in neural network analysis
  - pre-tagged sample used as control

Most stringent limits up to date!



Results

$$\sigma_{qg\to t} < 3.9\text{pb @ 95\%CL} \quad (< 2.4 \text{ pb exp.})$$

$$B(t \to ug) < 5.7 \cdot 10^{-5} \quad \text{, if} \quad \mathrm{B(t \to cg) = 0}$$

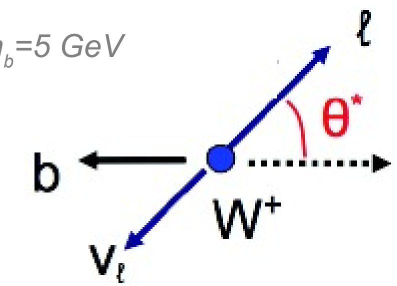
$$B(t \to cg) < 2.7 \cdot 10^{-4} \quad \text{, if} \quad \mathrm{B(t \to ug) = 0}$$

W polarization

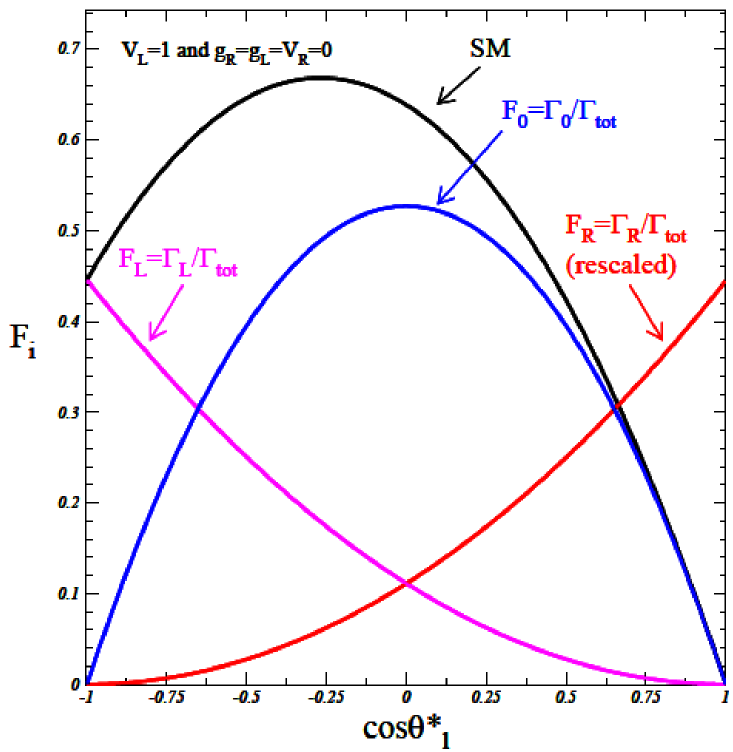
- **Measure θ*** , the angle between the lepton and the -b direction (W rest frame)
  - Distribution reflects 3 possible polarizations of the W boson

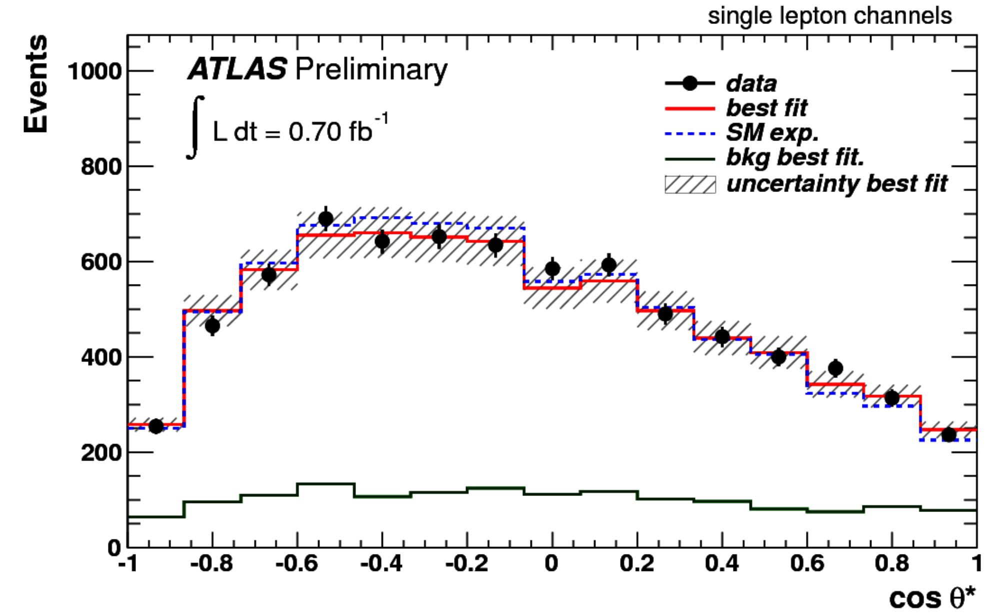
    $$F_0 = 0.698, \quad F_L = 0.301, \quad F_R = 4.1 \times 10^{-4}.$$

    for M_W=80.399 GeV, m_t=173.3 GeV, m_b=5 GeV
  - Anomalous tWb couplings lead to deviations of the W helicity fraction



- Measurement of fractions or asymmetries is **affected by** two aspects:
  - ***Detector effects***: distortions due to resolution, acceptance, …
  - ***Th./modeling uncertainties***: fixed grid polarization scan vs. generalizing generator level polarization to any scenario





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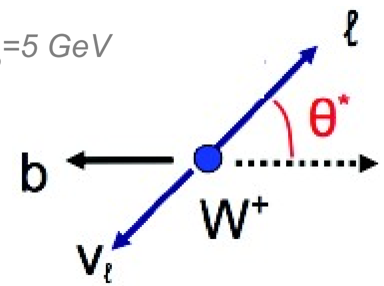

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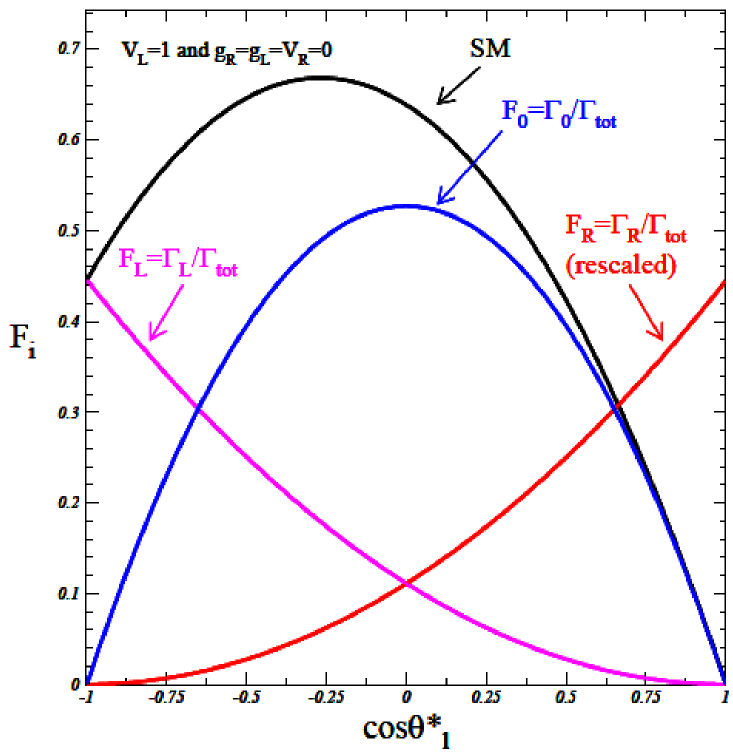
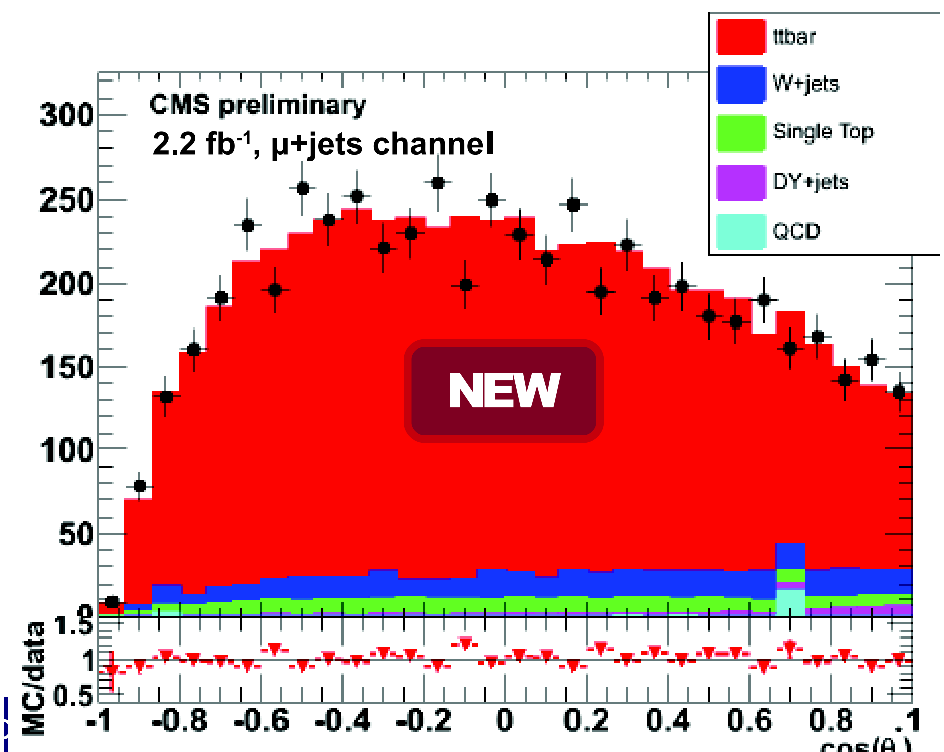
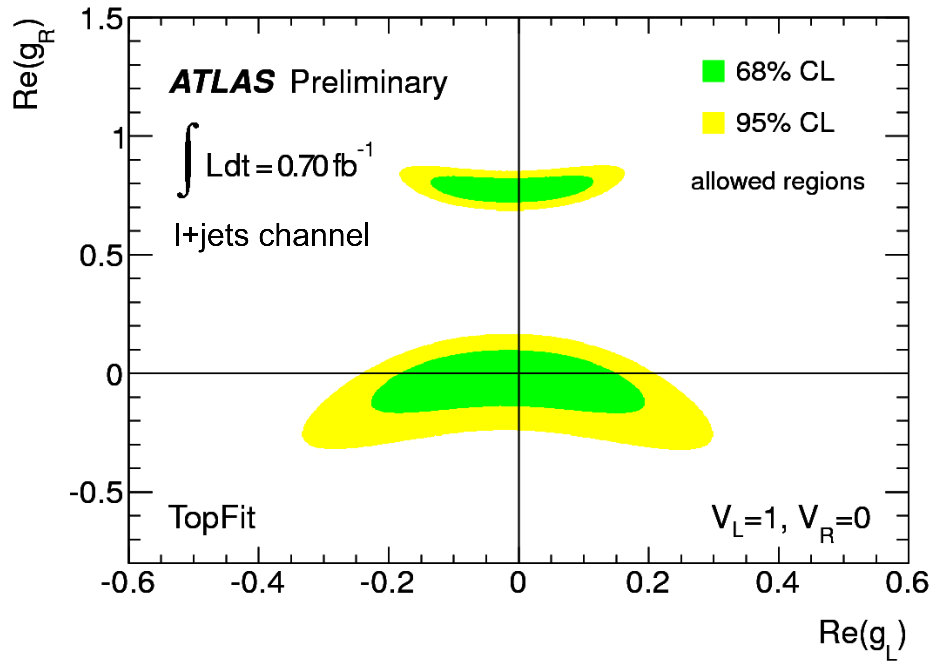
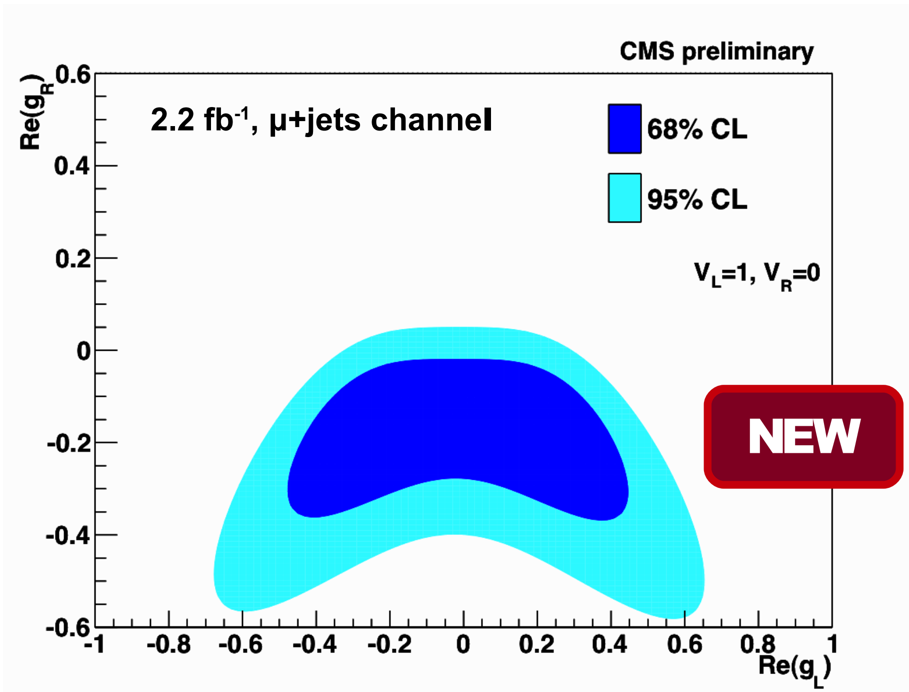




W polarization - results





Results

ATLAS

$$F_0 = 0.57 \pm 0.07\,(\text{stat.}) \pm 0.09\,(\text{syst.})$$
$$F_L = 0.35 \pm 0.04\,(\text{stat.}) \pm 0.04\,(\text{syst.})$$
$$F_R = 0.09 \pm 0.04\,(\text{stat.}) \pm 0.08\,(\text{syst.})$$

CMS

$$F_0 = 0.567 \pm 0.074(\text{stat.}) \pm 0.047(\text{syst.})$$
$$F_L = 0.393 \pm 0.045(\text{stat.}) \pm 0.029(\text{syst.})$$
$$F_R = 0.040 \pm 0.035\,(\text{stat.}) \pm 0.044(\text{syst.})$$

- Helicity fractions can be translated to constrain anomalous couplings and NP operators
  - e.g. the constrain in g_R yields:

ATLAS

$$\frac{\mathrm{Re}\,(C_{uW}^{33})}{\Lambda^2} \in [-2.27, 1.57]\ \text{TeV}^{-2}$$

CMS

$$\mathrm{Re}(C_{uW}^{33})/\Lambda^2 = -0.813 \pm 0.615\ (\text{stat.})^{+0.847}_{-0.951}(\text{syst.})\ \text{TeV}^{-2}$$

Top quark mass

Measurements in different channels and first individual combinations..

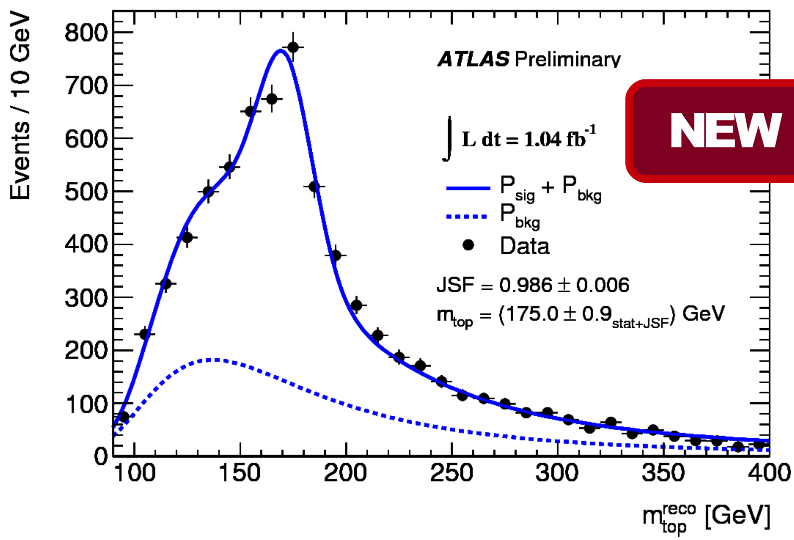
World's most precise top mass difference.

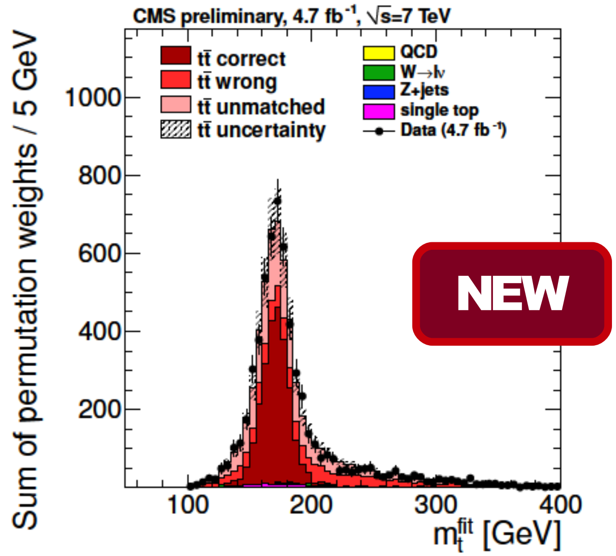
Lepton+jets measurements

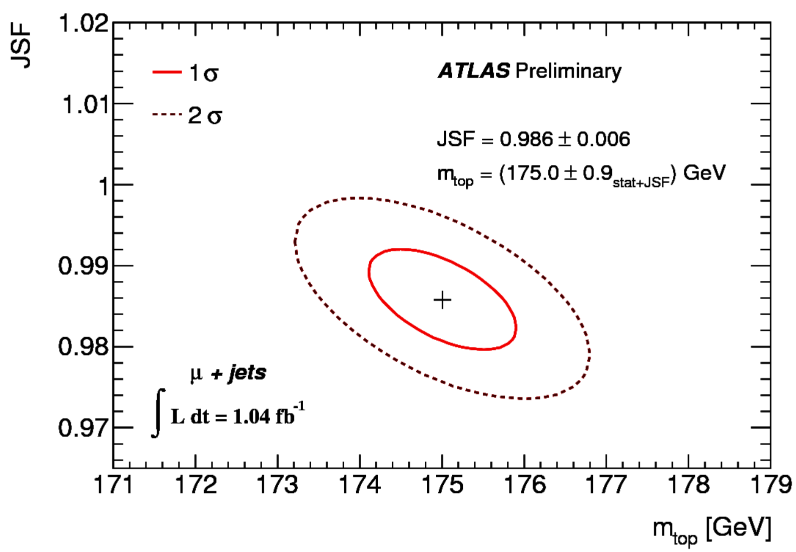
- **Channel allows for in-situ calibration of the light quark JES from W→ qq' leg**

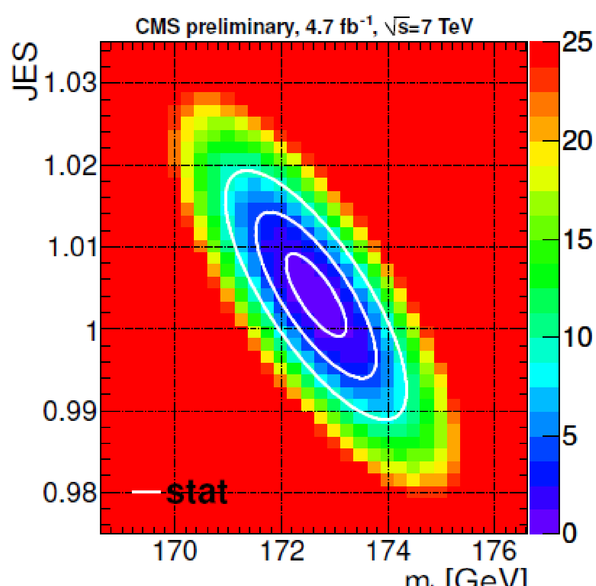
ATLAS: templated fit as function of JES and top mass

CMS: kinematic fit + **ideogram like method** → combine event-per-event likelihood









Results

ATLAS

$$174.4 \pm 0.6_{stat} \pm 2.3_{syst}\ \text{GeV}$$

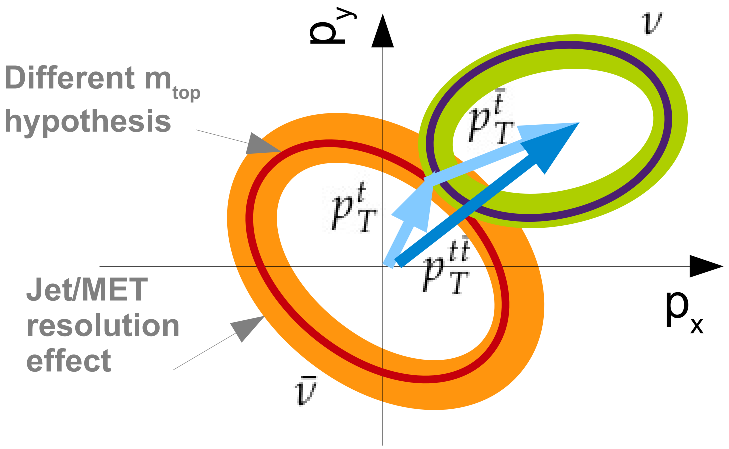
CMS

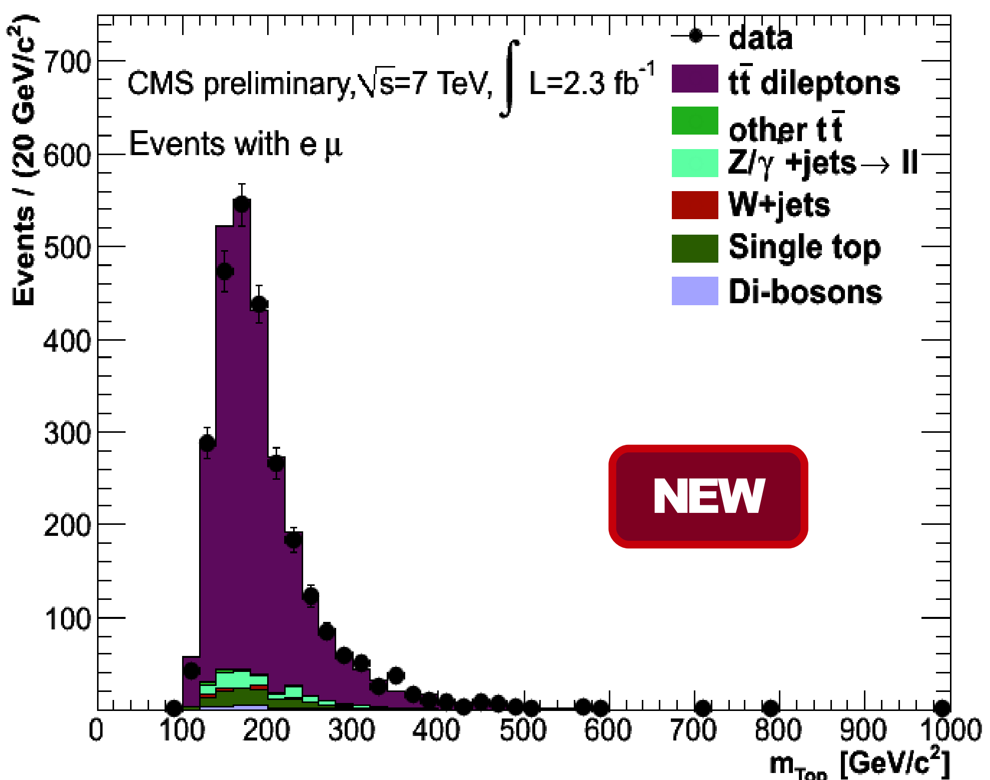
$$172.64 \pm 0.57_{stat+JES} \pm 1.18_{syst}\ \text{GeV}$$

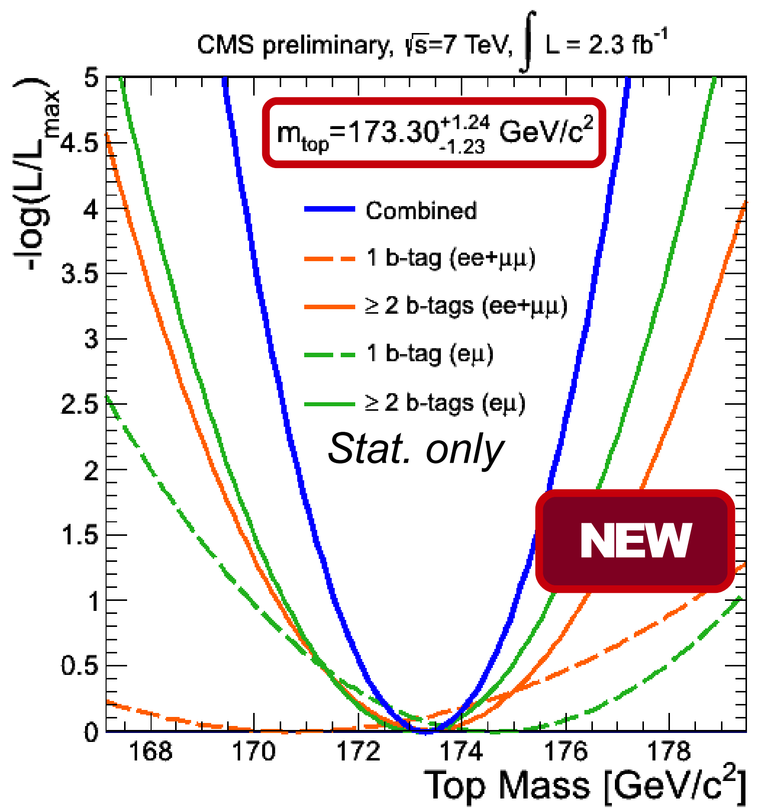
Note: Some systematics are still being evaluated by CMS (expected to be in %m_{top}: underlying event ~0.1%, color reconnection~0.4%)

Dilepton mass measurement

- One degree of freedom in the kinematics
  - Up to 8 possible solutions per event ▶
- **KINb method**: eq. solved numerically several times
  - most probable combination is picked up
- **Measure:** $173.3 \pm 2.8\ (\mathrm{stat} \oplus \mathrm{syst})\ \mathrm{GeV}$
  - dominated by JES uncertainty
  - **most precise up-to-date in the dilepton channel**

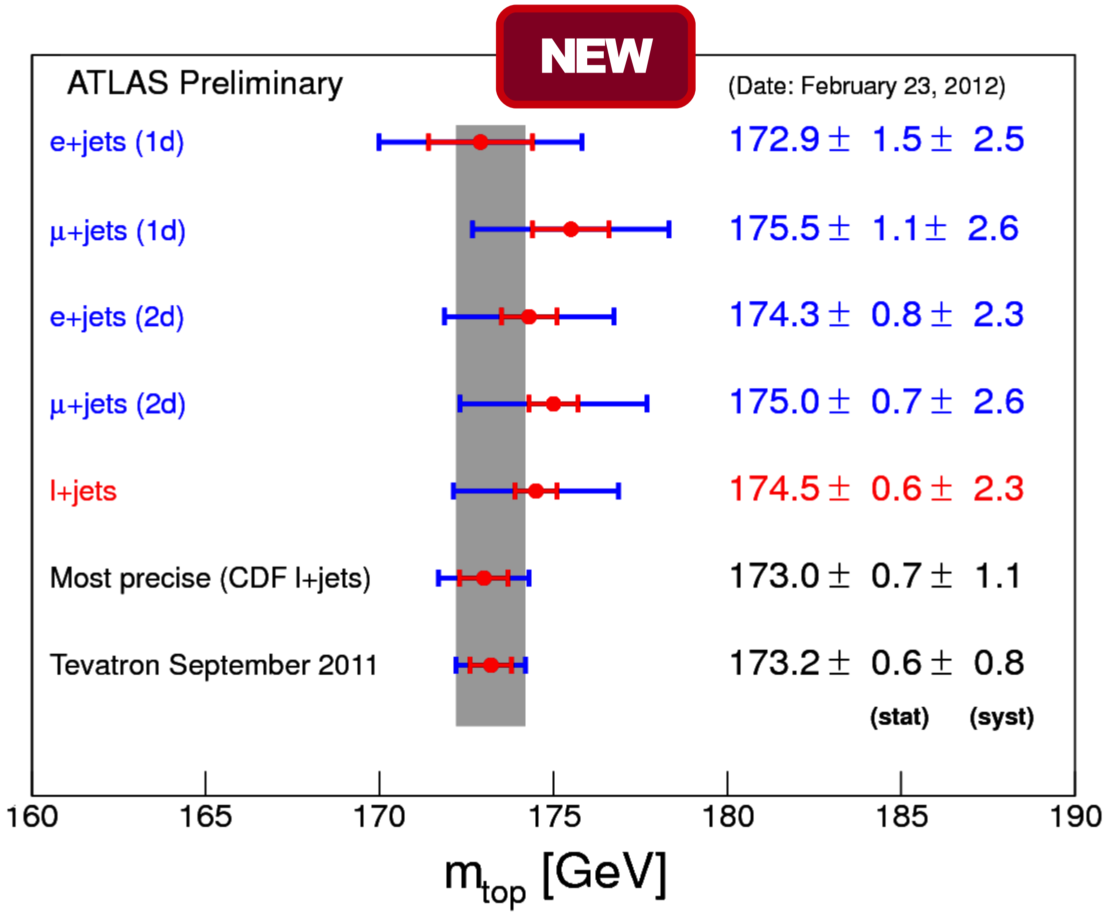


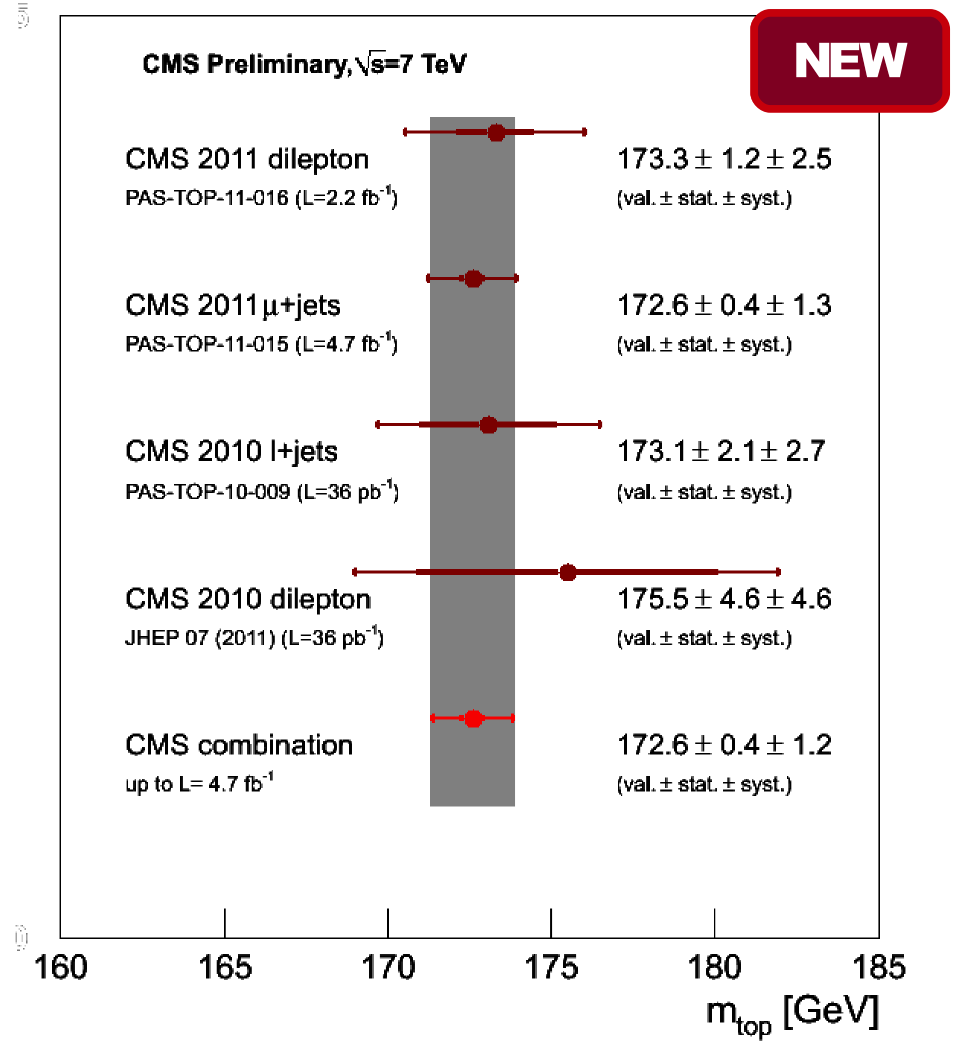




Top mass combination

CMS-PAS-TOP-11-018





- **… and LHC combination is on the way**
- "Back of the envelope" calculation indicates that result will help decrease the current uncertainty from the Tevatron (partially uncorrelated systematics + higher statistics)

Top mass difference

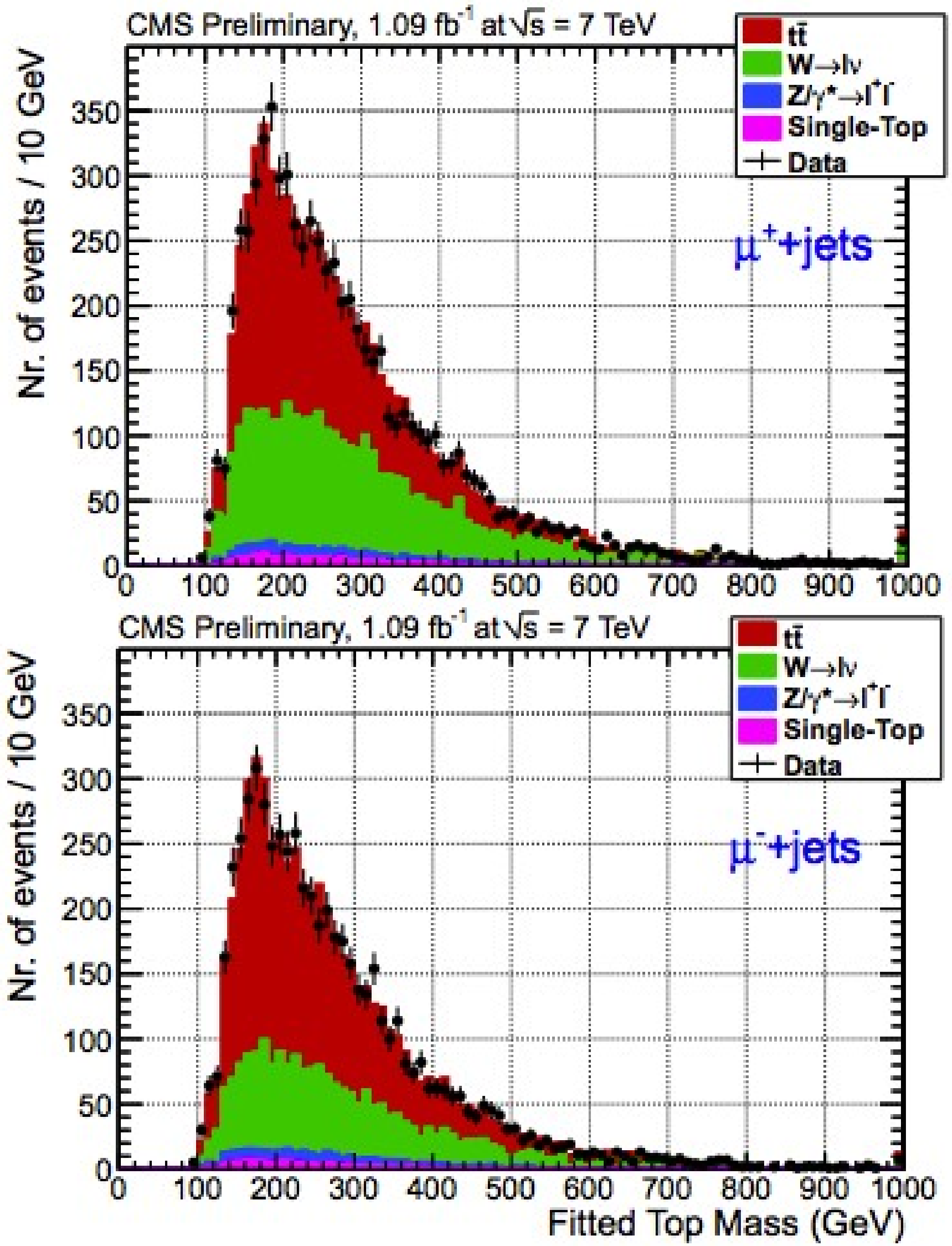
- **Test CPT invariance in the top quark sector: $m_{top}=m_{anti\text{-}top}$?**
- Compare μ^++jets vs μ^-+jets samples
- Mass reconstructed from hadronic side
  - Use kinematic fit (including resolutions)
  - Choose combination with lowest χ^2
- Final measurement from ideogram method (combine event-per-event likelihood for μ^- and μ^+ separately)
- **Most systematic effects cancel out**
- Measurement is stat. limited
- **World's best so far!**

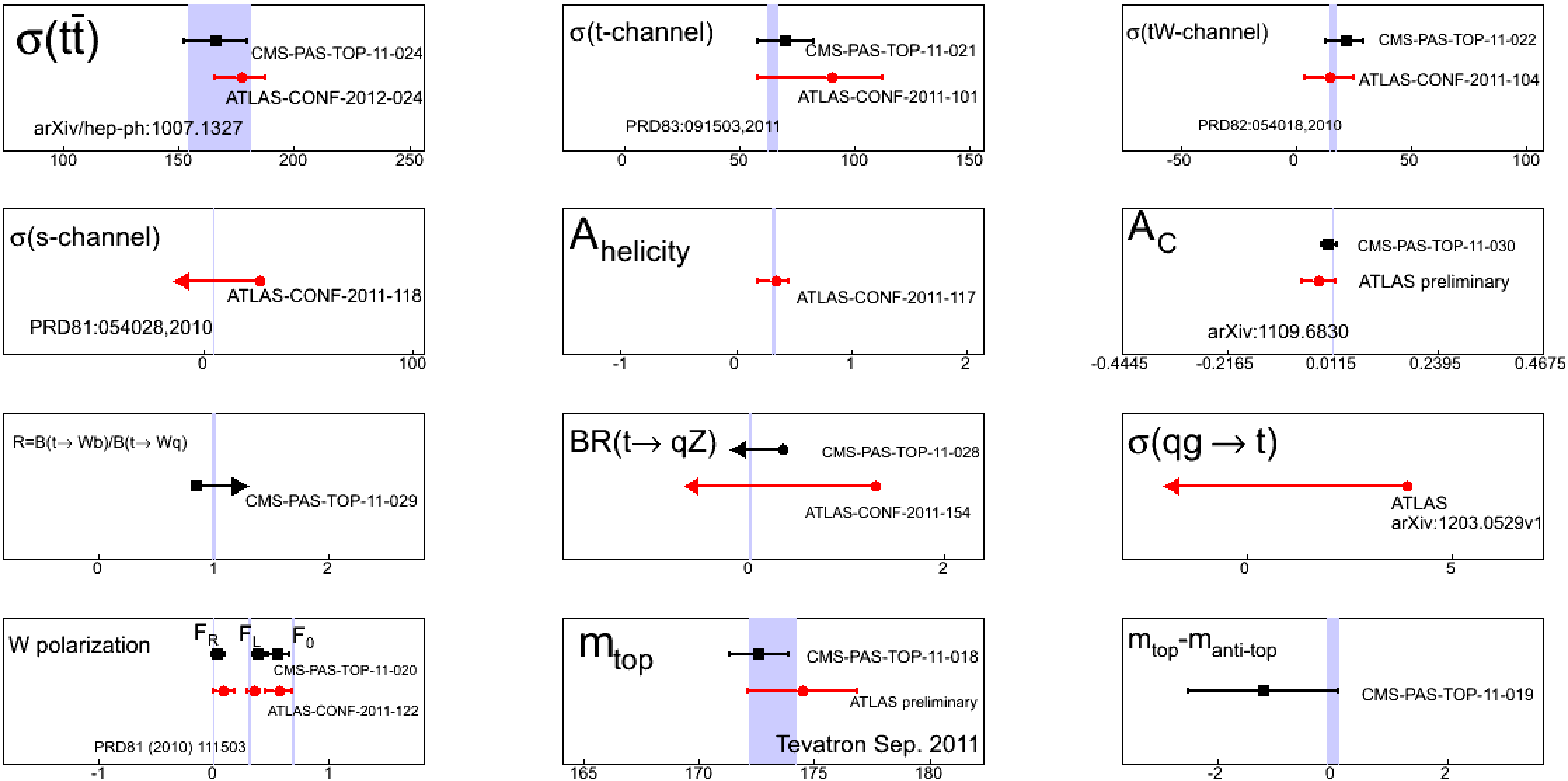
Results

CMS

$$\Delta m_t = -1.2 \pm 1.2\,(\text{stat.}) \pm 0.5\,(\text{syst.})\ \text{GeV}$$

- Result is consistent with the SM




σ(tt̄)
CMS-PAS-TOP-11-024
ATLAS-CONF-2012-024
arXiv/hep-ph:1007.1327
100
150
200
250
σ(t-channel)
CMS-PAS-TOP-11-021
ATLAS-CONF-2011-101
PRD83:091503,2011
0
50
100
150
σ(tW-channel)
CMS-PAS-TOP-11-022
ATLAS-CONF-2011-104
PRD82:054018,2010
-50
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PRD81:054028,2010
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CMS-PAS-TOP-11-030
ATLAS preliminary
arXiv:1109.6830
-0.4445
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0.4675
R=B(t→ Wb)/B(t→ Wq)
CMS-PAS-TOP-11-029
0
1
2
BR(t→ qZ)
CMS-PAS-TOP-11-028
ATLAS-CONF-2011-154
0
2
σ(qg → t)
ATLAS
arXiv:1203.0529v1
0
5
W polarization
F R
F L
F 0
CMS-PAS-TOP-11-020
ATLAS-CONF-2011-122
PRD81 (2010) 111503
-1
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1
m top
CMS-PAS-TOP-11-018
ATLAS preliminary
Tevatron Sep. 2011
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170
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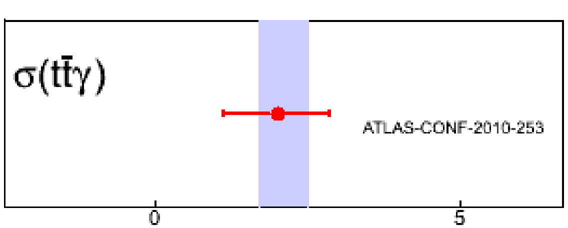

σ(tt̄γ)
ATLAS-CONF-2010-253
0
5

Summary

Conclusions

- **2011** has been a **great year for top quark physics**
  - Good collection of results were recently made public by the LHC experiments

    ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults

    CMS: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP
  - **Results contribute effectively to a more precise knowledge of the top quark**

    e.g. cross section, perturbative QCD, FCNC, charge asymmetry,

    mass, mass difference, R_b, W polarization.
  - Much more to come in the near future

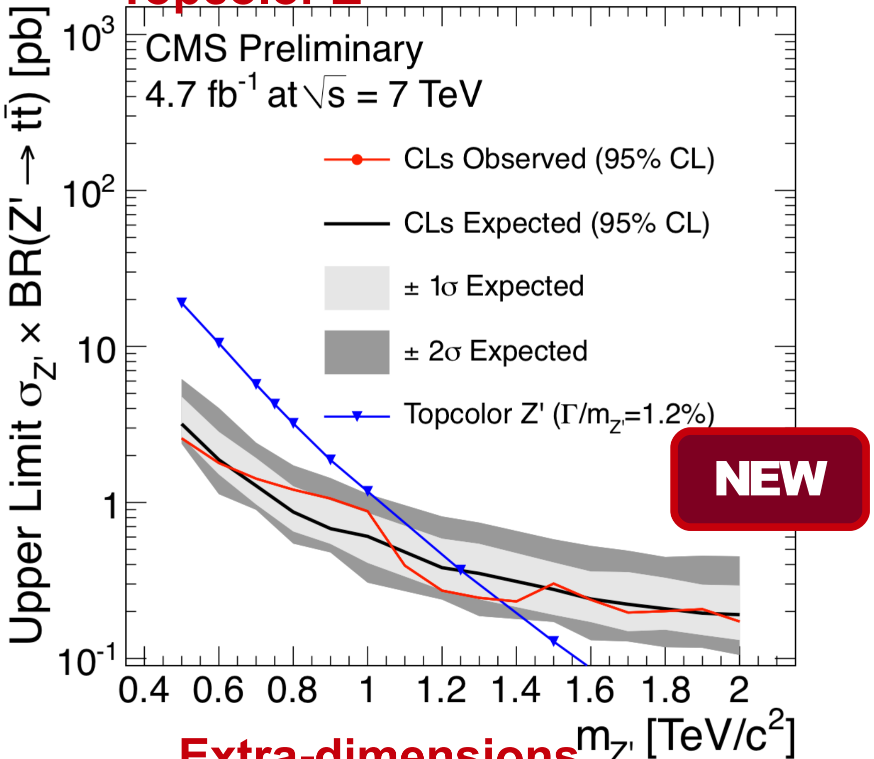
- **BSM searches uncovered in this talk but many results are out**...

... no evidence of BSM effects in the top quark sector up to now...

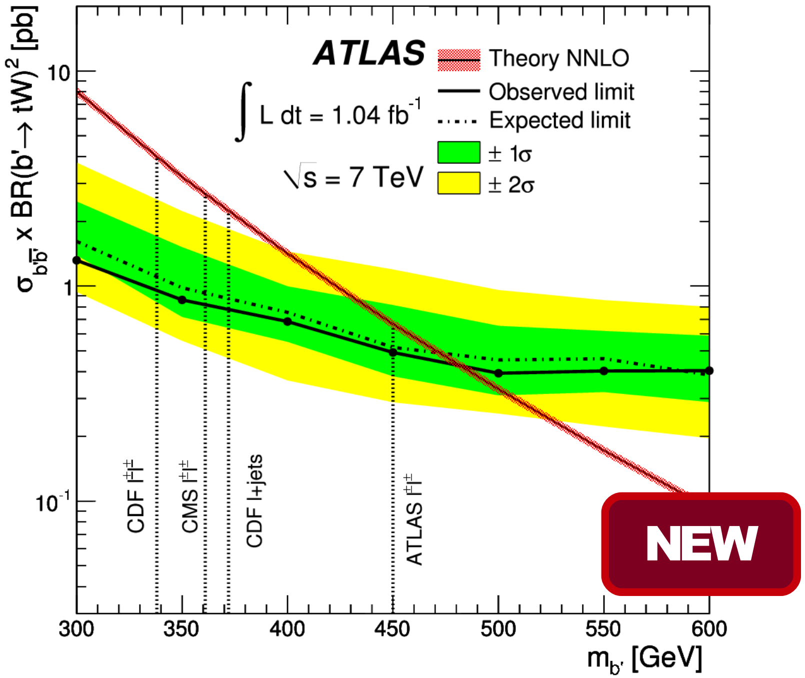
but we'll keep searching for it with >15 fb^{-1} @ 8TeV to be kindly delivered by the LHC in 2012

Aknowledgments: top quark group conveners M. Cristinziani, M. Costa, R. Chierici, R. Tenchini and analysts for the input received and for granting the speaker the chance to represent their work.

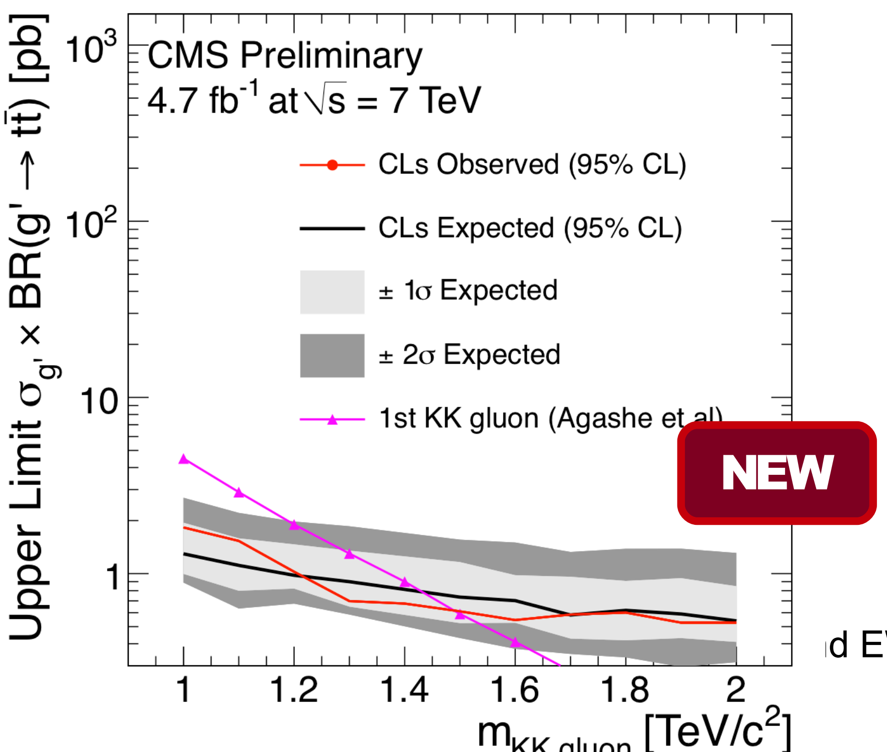
Topcolor Z'



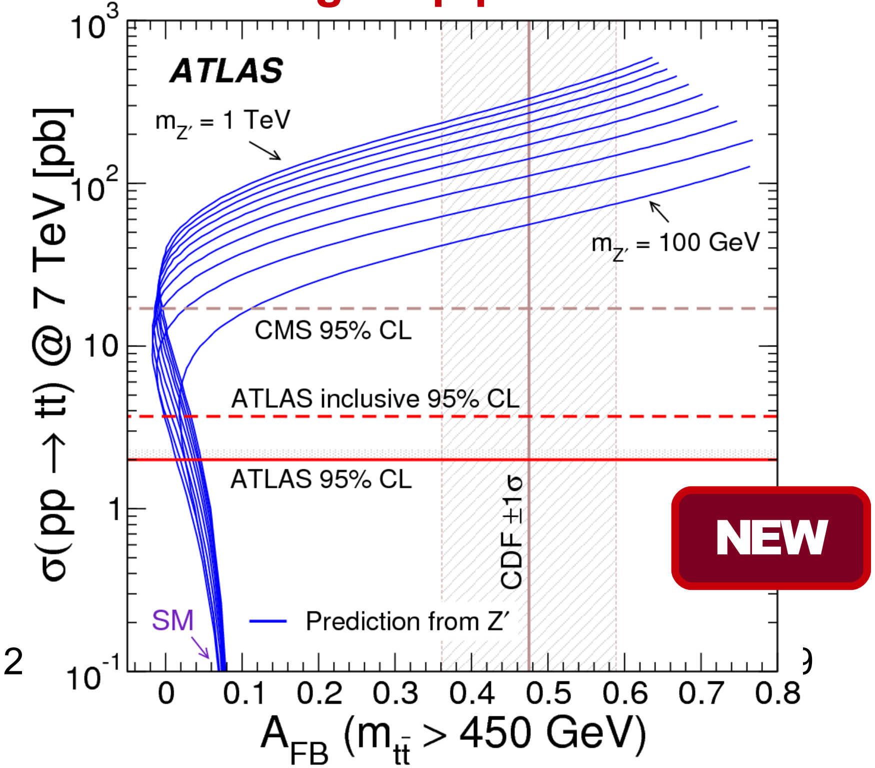
4th gen. down-type quarks



Extra-dimensions



Same sign top pairs



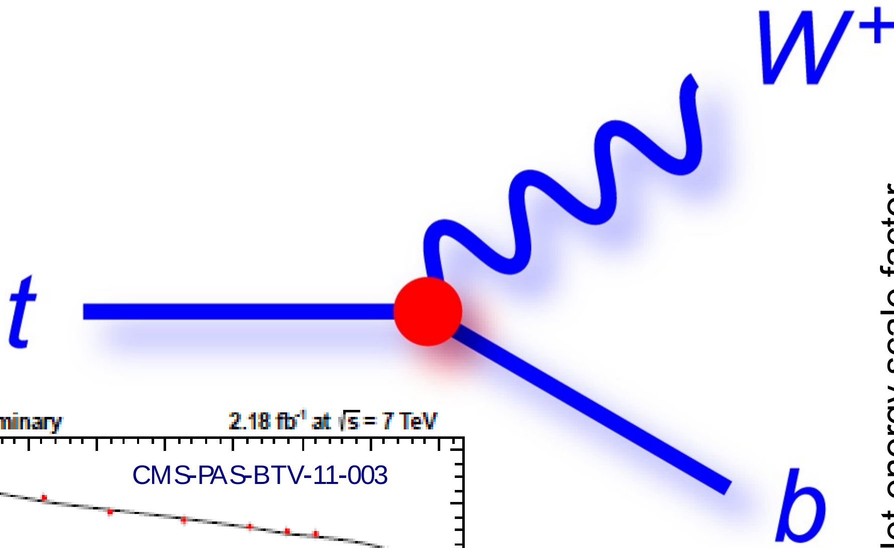
Backup

The LHC has delivered us >10^6 top quarks last year – what have we learnt?

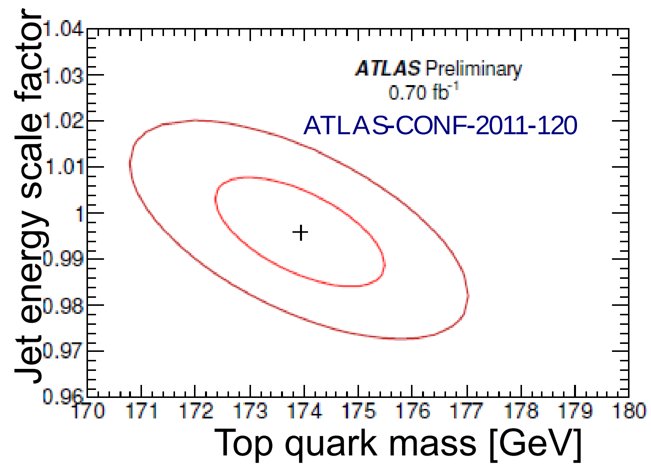
The experimental physicist point of view

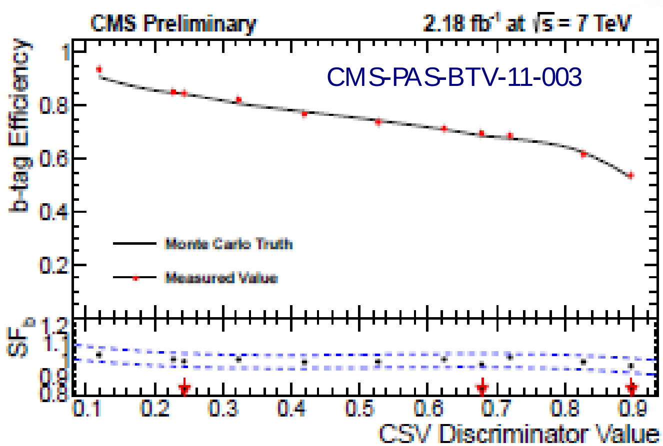
In the context of the SM: $M_{top} \approx 173$ GeV/c^2 and $B(t \rightarrow Wb) \approx 1$

*$M_{top}{}^2 = (P_b + P_W)^2$ can be used to derive the **b-jet energy scale***



*$M_W{}^2 = (P_q + P_{q'})^2$ constraints the **light jet energy scale*** ▼



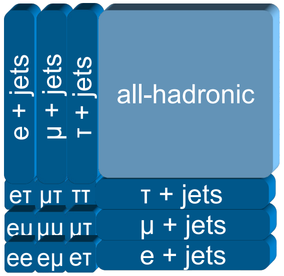


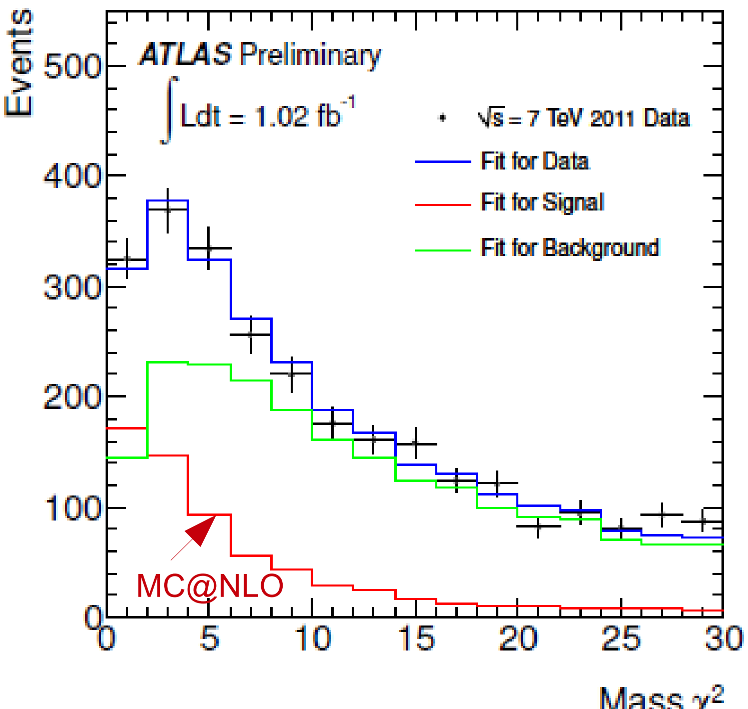
◄ *Direct measurement of the **b-tag efficiency***

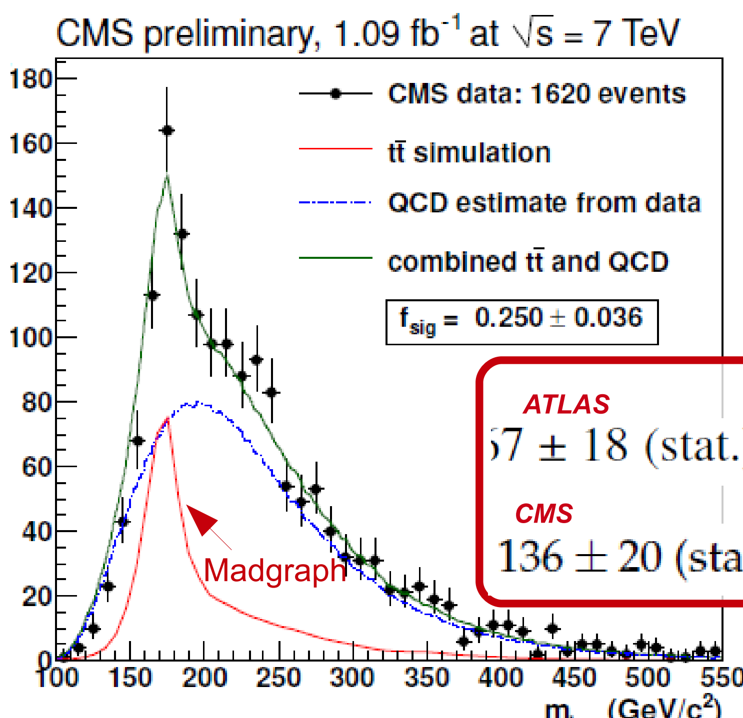
Top provides a unique sample for the calibration of our detectors

All hadronic channel

- Select **at least 6 jets** (thresholds depend on trigger turn-on)
  - b-tagging reduces combinatorics
- **Correct combination of jets reconstructs m_{top} from:**
  - min χ^2 with fixed m_t or Kinematics fit with m_t=$m_{anti\text{-}top}$
- Multijet **QCD**, main background, **modeled from data**
  - model χ^2 using event mixing from 4-5 jet events (A)
  - re-weight mass spectrum obtained in control region with 0 b-tags (C)







◀ Fit σ from data
(signal from generator, background data-driven)

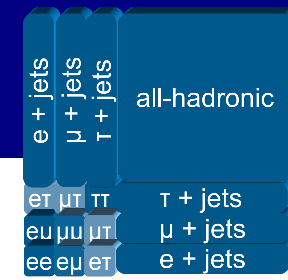
$$\sigma_{t\bar{t}} = \frac{f_{sig} \cdot N}{\epsilon \cdot L_{int}}$$

Results

ATLAS
…7 ± 18 (stat.) ± 78 (syst.) ± 6 (lum.) pb

CMS
136 ± 20 (stat.) ± 40 (sys.) ± 8 (lumi.) pb

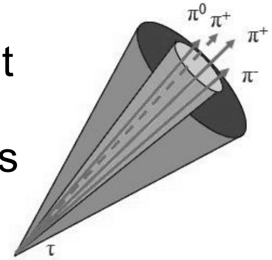
τ dilepton channel



τ reconstruction

Multivariate based indentification *ATLAS*

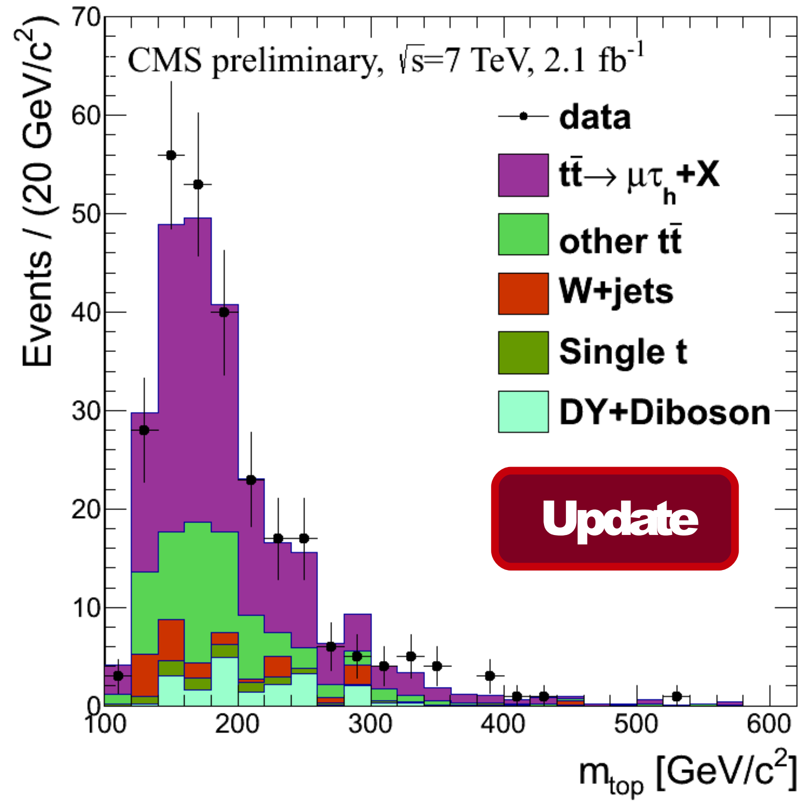
- Use BDT to identify τ from reconstructed jet
- Variables depend on # of prongs
- e.g. radius and energy fraction of EM/tracks



Hadron + strips *CMS*

- particle flow based: use mass of charged hadrons and γ
- γ/e clustered in strips along bending plane (identify π_0)
- different combinations = different τ decay modes

- **Rely on isolated e/μ probe and search for OS τ**
  - Require at least two jets (one b-tagged)
  - Significant E_T^{miss}
- **Determine from data τ fakes**
  - dominated by light flavor jets contribution
  - In W+jets gluon contribution canceled by OS-SS
  - Conservative approach: average W+jets and QCD



Results

ATLAS

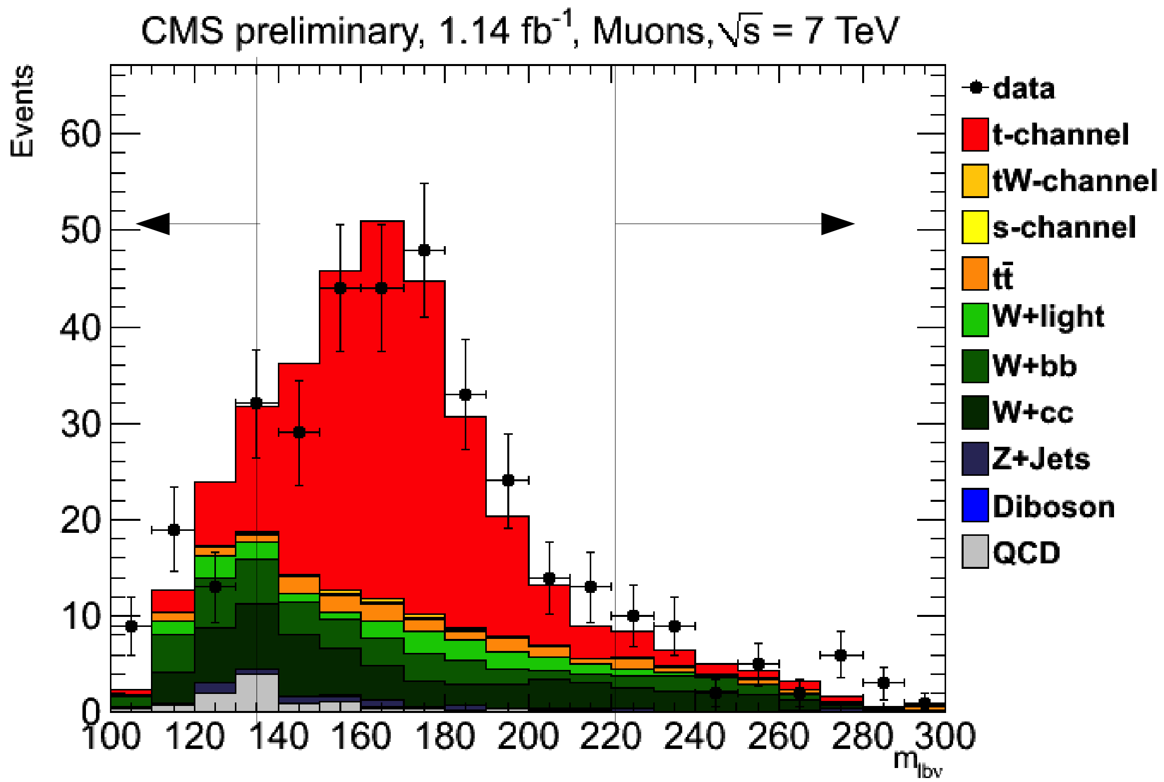
$$142 \pm 21\ (\text{stat.}) \pm^{20}_{16}\ (\text{syst.}) \pm 5\ (\text{lumi.})\ \ \text{pb}$$

CMS

$$151 \pm 15(\text{stat.}) \pm 23(\text{syst.}) \pm 7(\text{lumi.})\ \text{pb}$$

Background control for t-channel

- **QCD multijets** is controlled in the 2 jet 1 tag sample after fitting the low M_T region for the muon channel (low E_T^{miss} region for the electron channel)
- Check shape and normalization of $|\eta_j|$ and m_{lvb} in 2 control regions:
  - 2 jets 0 tags: **W+light**
  - 3 jets 2 tags: **Ttbar**
- **W+ heavy flavor** production is the main background
  - From EWK/ Ttbar cross section measurement it is expected to be 1.2 (W+b) / 1.7x (W+c) larger with respect to MC prediction
  - Control $|\eta_j|$ in the m_{lvb} sidebands ▶
  - Subtract TTbar, single top-s, -tW and dibosons from prediction
  - Derive the template for the W+heavy flavor contribution to be fit in the signal region



Effective field theory for charge asymmetry anomaly

Effective axial-vector coupling of gluon as an explanation of the top quark asymmetry

PRD 84:054017,2011

Emidio Gabrielli[1,*] and Martti Raidal[1,†]

Implications of the effective axial-vector coupling of gluon on top-quark charge asymmetry at the LHC

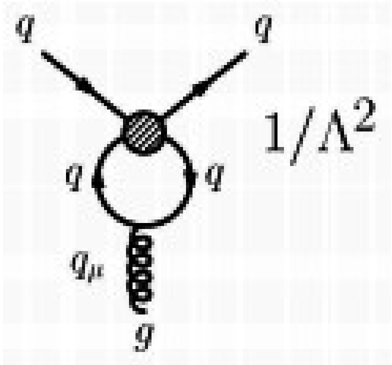
arXiv:1112.5885

Emidio Gabrielli,[1,*] Martti Raidal,[1,†] and Antonio Racioppi[1,‡]

Our proposal consists in **adding an anomalous effective axial-coupling to the gluon with quarks** that is induced at one loop level.

$$\boxed{g_S \frac{q^2}{\Lambda^2} F\left(\frac{q^2}{\Lambda^2}\right) [\bar{Q}\gamma^\mu\gamma_5 T^a Q] G^a_\mu .}$$

We treated this vertex in the approximation of the effective theory. Color gauge invariance requires that such a coupling must vanish with vanishing external momenta, namely $g_A(q^2) \sim q^2/\Lambda^2$, where **$\Lambda$ is the scale of new physics** assumed to be larger than any other scale in the set up.



In this framework the observed Tevatron TTbar anomaly can be explained in a consistent way with a universal anomalous gluon coupling with Λ of order of TeV. **Because of the q^2 behaviour of the effective coupling, this scenariois testable at the LHC**.