Top Physics Results from the ATLAS Experiment

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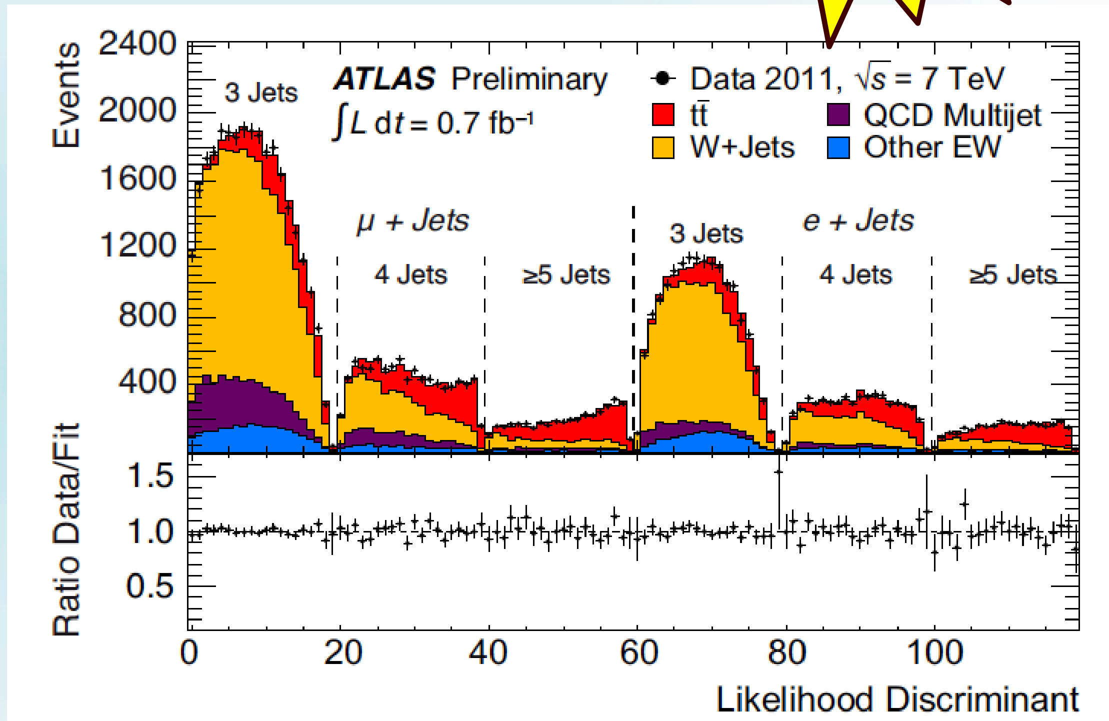
Cross Sections

$\sigma_{t\bar{t}}$ single lepton (no b-tagging)

- Analysis with 0.7 fb^{-1}
- Kinematical differences between tt and W+jets
- **likelihood discriminant**
  - lepton η, leading jet p_T, aplanarity, transverse momentum of all jets but the two leading ones
- **Fit in 6 channels**:
  - 3, 4 and >= 5 jets; e, μ
- Main systematics:
  - signal modelling (choice of signal MC generator, ISR/FSR) , jet energy scale (JES)

δσ ~7%



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$\sigma_{t\bar{t}}$ = 179.0 ± 3.9(stat) ± 9.0 (syst) ± 6.6 (lumi) pb

$\sigma_{t\bar{t}}$ single lepton (b-tagging)

- Multivariate method on 35 pb-1 → split in 6 channels (=3,=4,≥5 jets; e/μ)
- Input variables: lepton η, exp(-8*aplanarity), exp(3*$H_{T,\,3p}$), b-tag weight
- Profile likelihood fit extracts 16 parameters including $\sigma_{t\bar{t}}$
- Main systematics:
  - W+jets HF content (7%)
  - Tagger calibration (7%)

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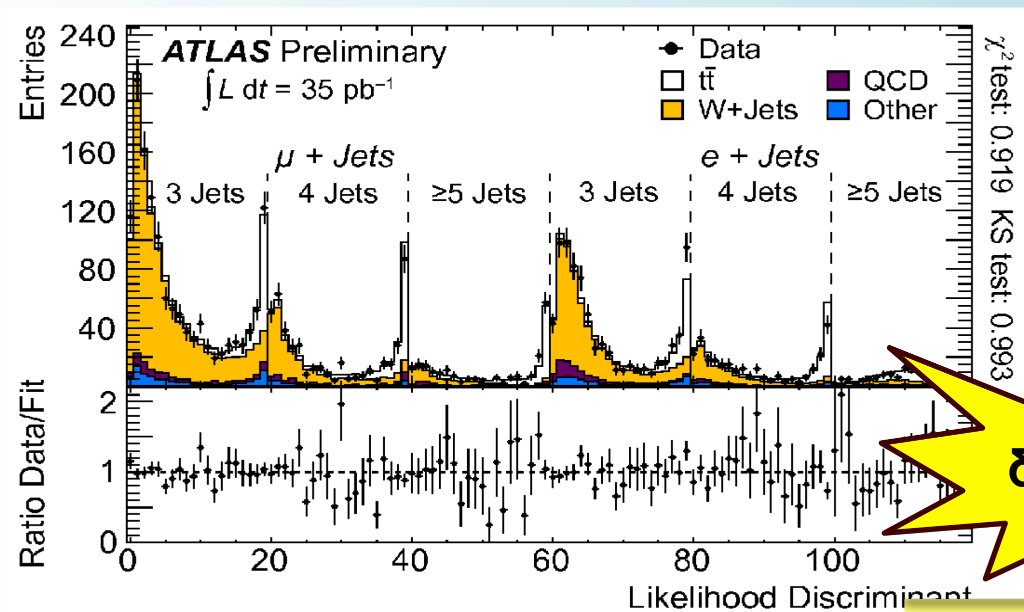
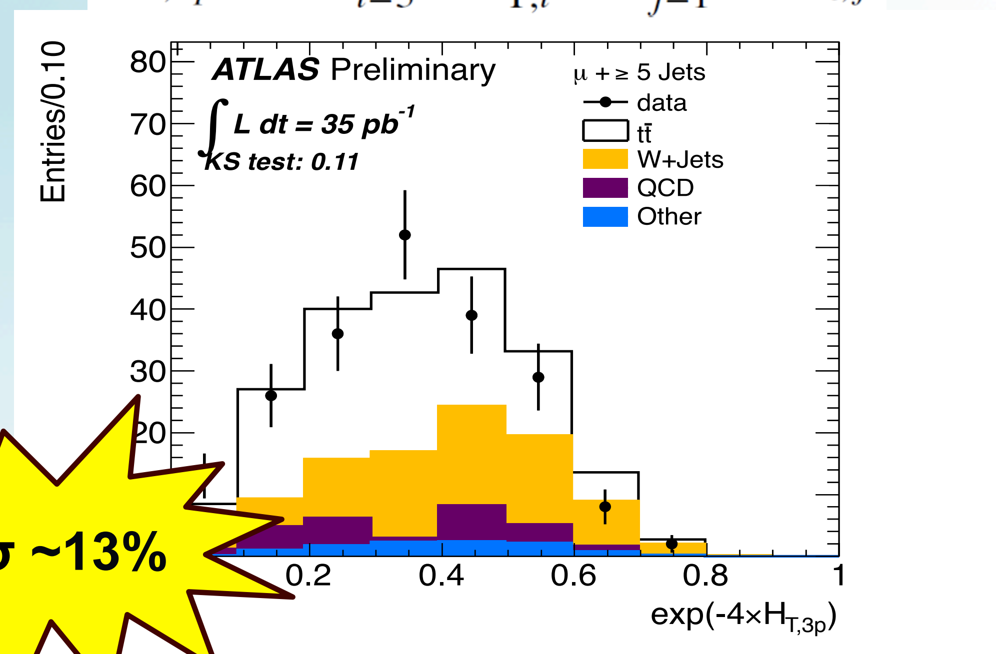
$$H_{T,3p} = \sum_{i=3}^{N_{\rm njets}} |p^2_{{\rm T},i}| / \sum_{j=1}^{N_{\rm objects}} |p_{z,j}|$$





δσ ~13%

σ_{tt} = 186 ± 10(stat) $^{+21}_{-20}$(syst) ± 6(lumi) pb

σ_{tt} dilepton

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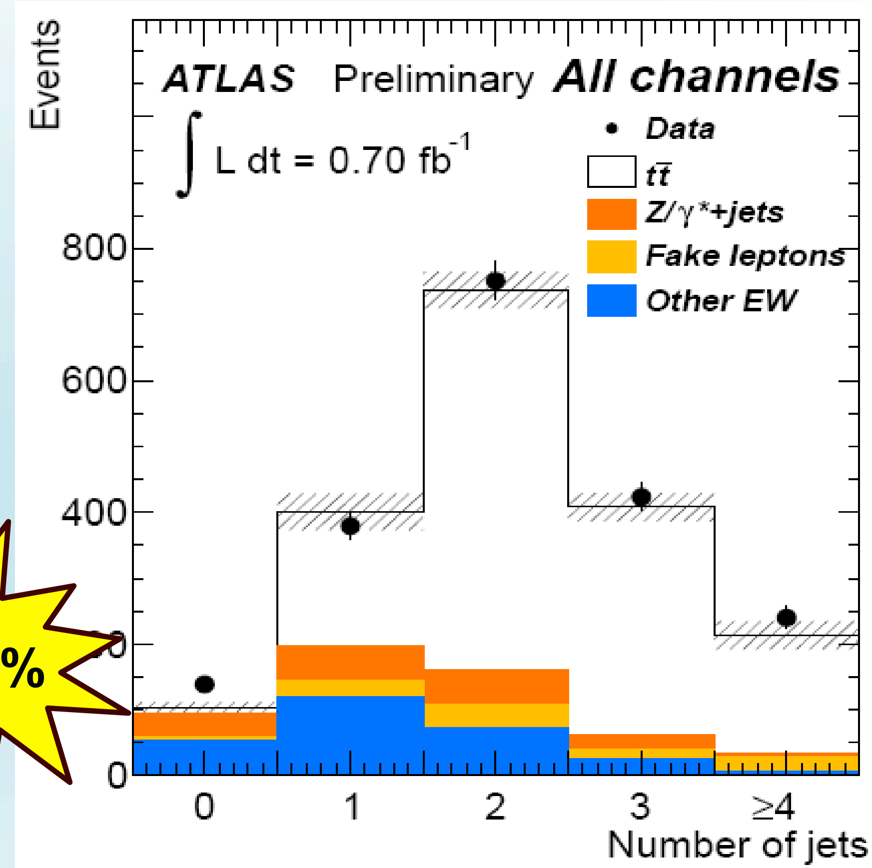
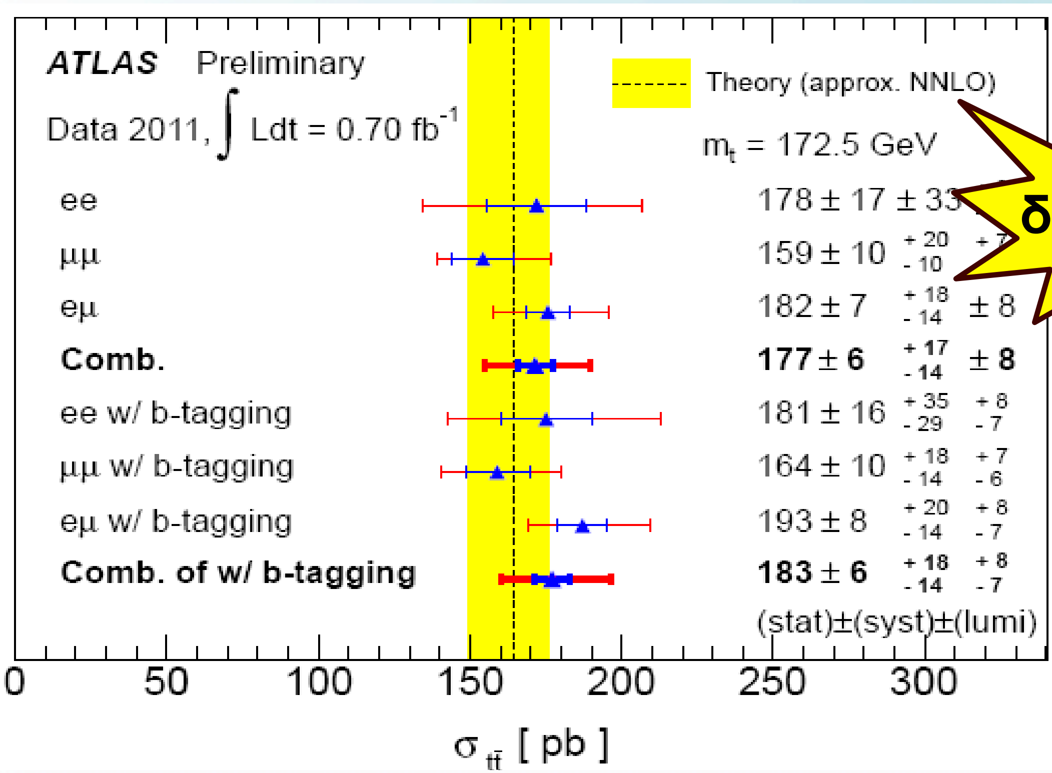
- Data corresponding to **0.70 fb⁻¹**
- Two counting analysis **with/without** the request of a b-tagged jet
- Main backgrounds estimated from data:
  - QCD
  - Z+jets





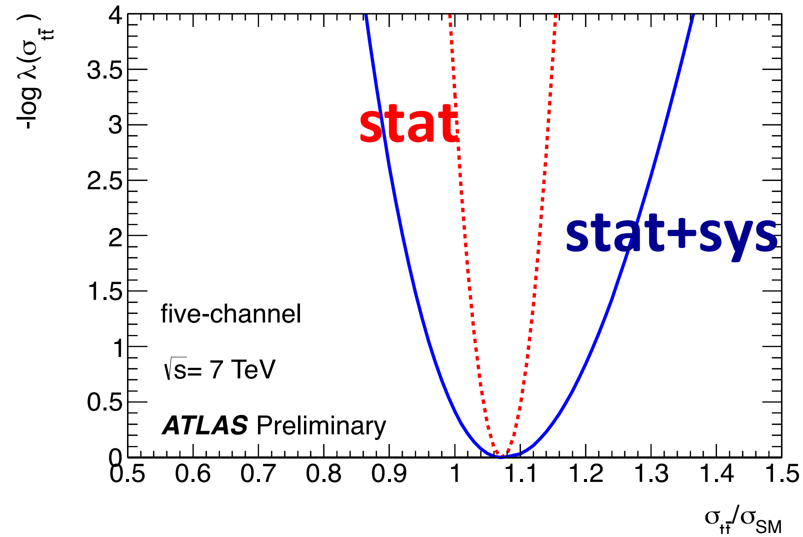
δσ ~11%

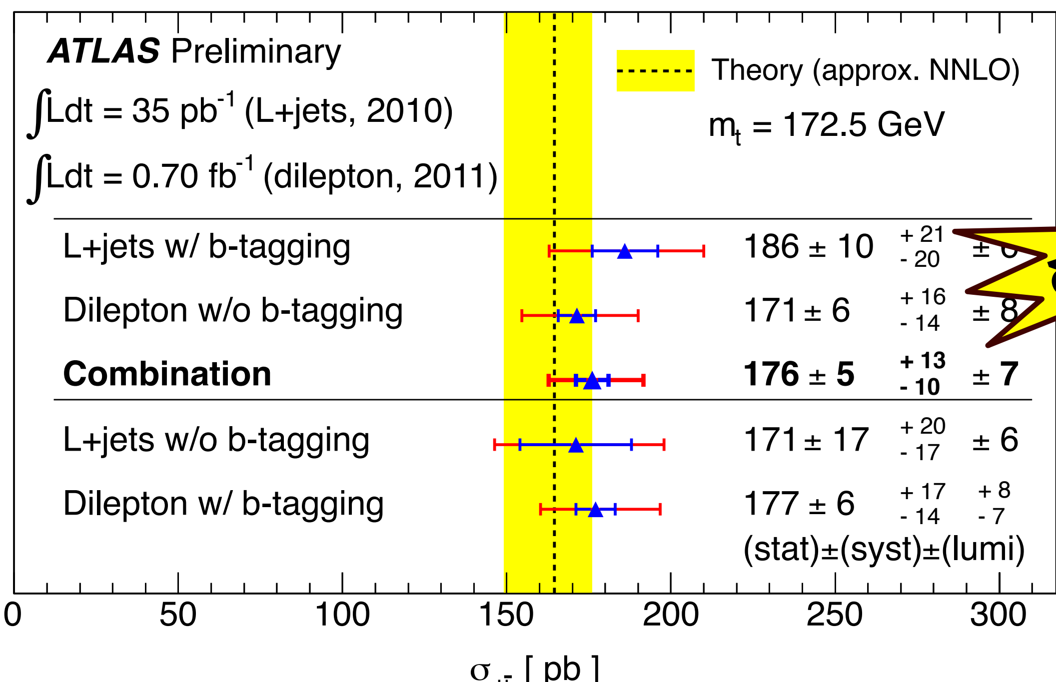
- Main systematics:
  - JES
  - luminosity
  - b-tagging efficiency (tag analysis)

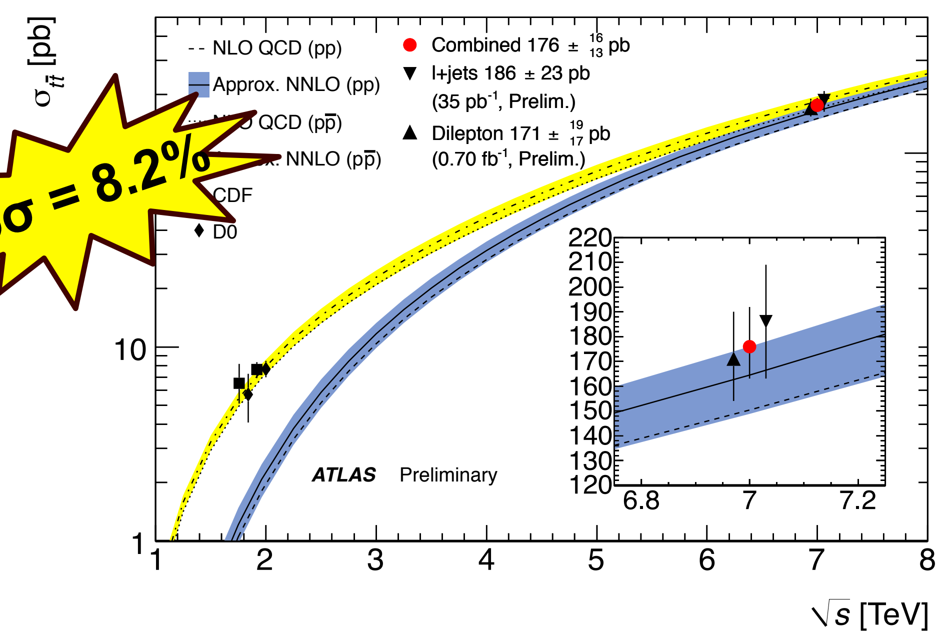
$\sigma_{t\bar{t}}$ combination

- Combined dilepton and single lepton channels
  - Single lepton with b-tag, dilepton w/o b-tag
  - Statistical uncertainty ~4%
  - Systematic uncertainty ~8%
  - Luminosity uncertainty ~3%

σ_{tt} = 176± 5(stat) $^{+13}_{-10}$(syst) ± 7 (lumi) pb







Inclusive cross section: μ+τ

- Motivation: decays like **t→bH⁺** can enhance BR of final states involving τ-leptons
- Analysis on **1.1 fb⁻¹**, with **one μ and one hadronically decaying τ**
  - event selection: 1 μ, 1 τ-jet (with one track τ_1 and with three tracks τ_3) and two other jets, one of them passing b-tagging
- Boosted decision trees (BDT) used to identify τ's and reject electrons and jets
- Signal fractions from a fit on BDT_j
  - backgrounds templates using control samples in data
- Main systematics:
  - τ-identification,
  - ISR/FSR modelling
  - b-tagging

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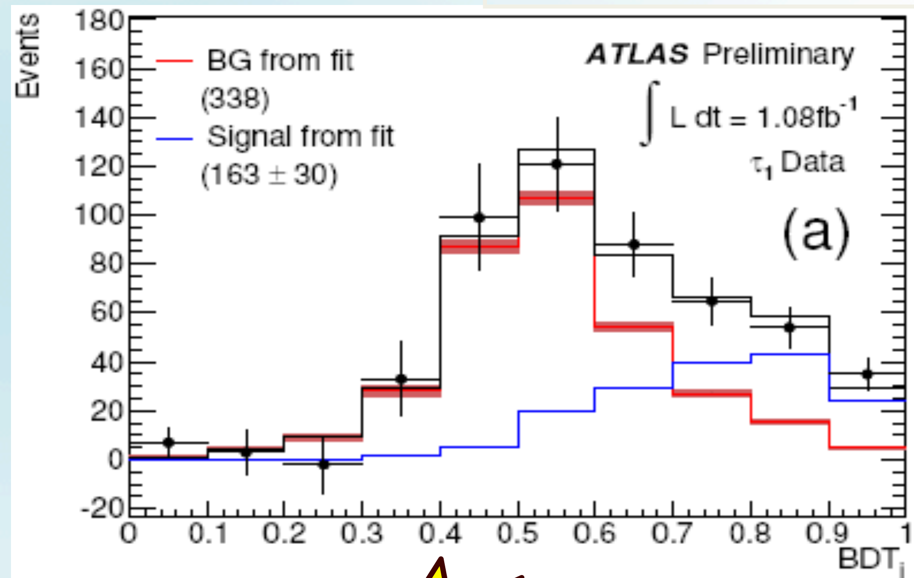


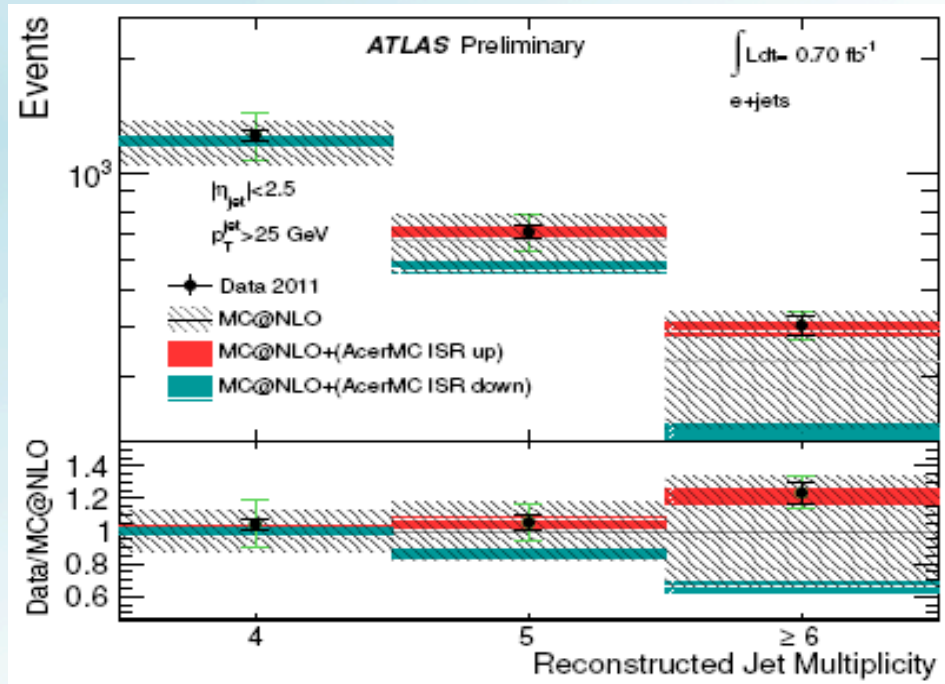
$\delta\sigma = 20\%$

σ_{tt} = 142 ± 21(stat) $^{+20}_{-16}$(syst) ± 6 (lumi) pb

Jet multiplicity in $t\bar{t}$ events

- Motivation: jet multiplicity measurement gives the **possibility to constrain ISR at m_{top} energy**
- Analysis based on **0.70 fb^{-1}** in **l+jets** channel
- QCD and W+jets backgrounds estimated from data
- Jet multiplicity distribution after background subtraction compared to different MC predictions:
  - **ISR varied within the uncertainty**

- Main uncertainties:
  - at low jet multiplicity (4 jets): QCD and W+jets backgrounds
  - at high jet multiplicity: JES



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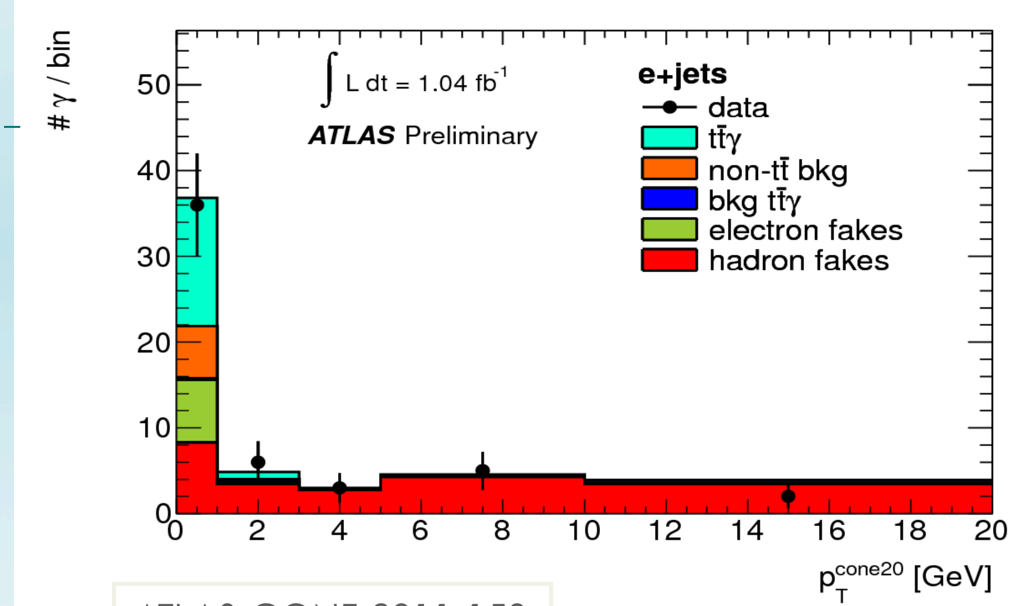
Present uncertainty: no discrimination

$t\bar{t}\gamma$

NEW

- Motivation: knowledge of the tγ vertex
- **1.04 fb^{-1}** of data in **l+jets** channel
- Single lepton selection, **+** presence of **one photon,** $p_T > 15$ GeV and $|\eta| < 2.5$, not close to a jet:
- Backgrounds:
  - from control regions in data: tt with fakes, W+jets + γ, QCD + γ
  - from MC: diboson, single top, Z+jets + γ/electron fake
- Signal fraction extracted from a fit on photon tracking isolation:
  - templates for signal and backgrounds from data
- Main systematics: γ ID, γ purity, JES, b-tagging, ISR/FSR
  - higher statistics will help in reducing γ contribution



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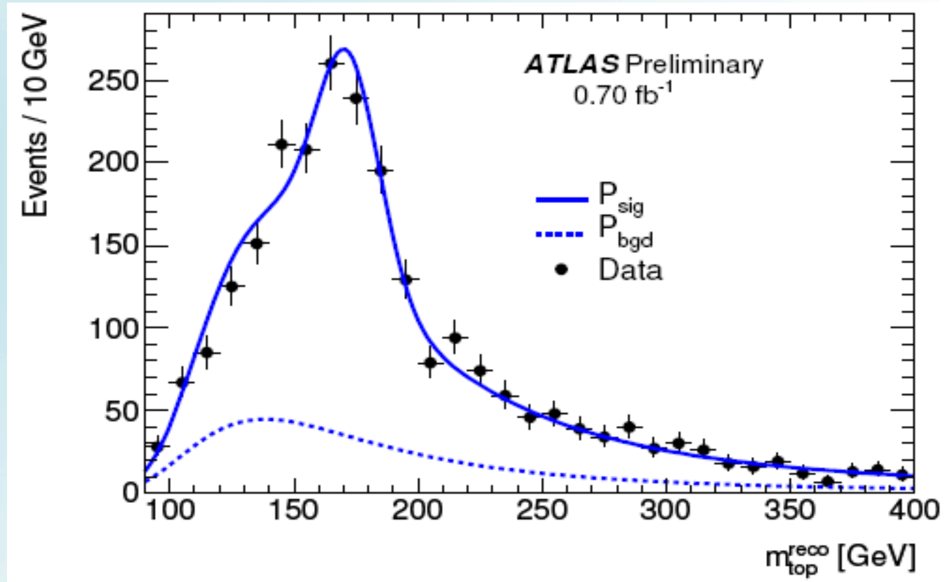
$\sigma_{tt\gamma}$ = **2.0 ± 0.5(stat) +0.7(syst) ± 0.08 (lumi) pb**

Properties

Top quark mass

- Motivation: large contribution to e-weak radiative corrections from m_{top}
  - constrain Higgs boson mass from precision measurements
- Analysis performed with **0.70 fb^{-1}** in **l+jets** channel,
  - asking the presence of one b-jet
- 3-jet from hadronic top: combination with higher total p_T
- Technique: **m_{top} and JES determined simultaneously**
  - W mass and width used as constraints
- m_{top}^{reco} in data have been compared to signal + backgrounds templates with ≠ JES and m_{top}
  - m_{top} and JES from a likelihood fit

- Main systematics:
  - ISR/FSR
  - signal modelling
  - JES for light jets and b-jets



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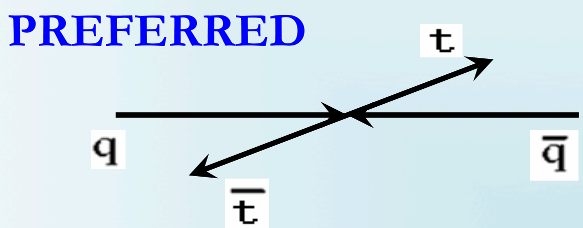
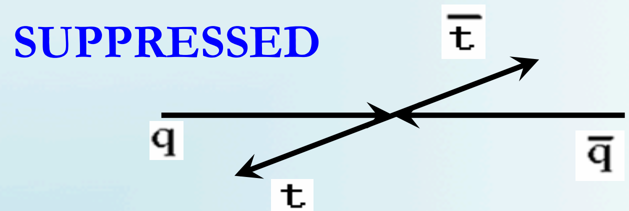
m_{top} = 175.9 ± 0.9(stat) ± 2.7(syst) GeV

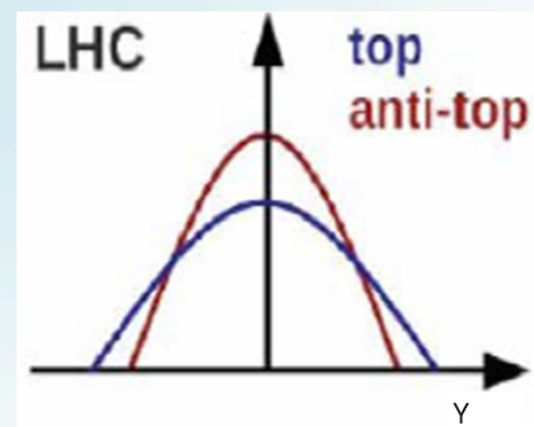
Charge asymmetry I

- Charge asymmetry only in asymmetric initial states
  - main contribution: quark-antiquark annihilation





- Valence quarks more boosted than sea antiquarks
  - top more boosted than antitops
  - broader rapidity



- Sensible observables to the asymmetry:

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

where $\Delta|Y| = |Y_t| - |Y_{\bar{t}}|$

- In SM asymmetry only at NLO: A~1%

Charge asymmetry II

- Data: **0.70 fb^{-1}** in **l+jets** channel
- Standard l+jets selection, b-tagging
- W+jets and QCD backgrounds from data, other backgrounds from MC
- **Event kinematics** reconstructed with a kinematic likelihood fitter
  - input: p_T, η, Φ of decay products
  - constraints from m_t, m_W, Γ_t and Γ_W
  - b-tagging info taken into account
- Bayesian unfolding used to correct for acceptance and detector effects
- Main systematics:
  - signal modelling and JER

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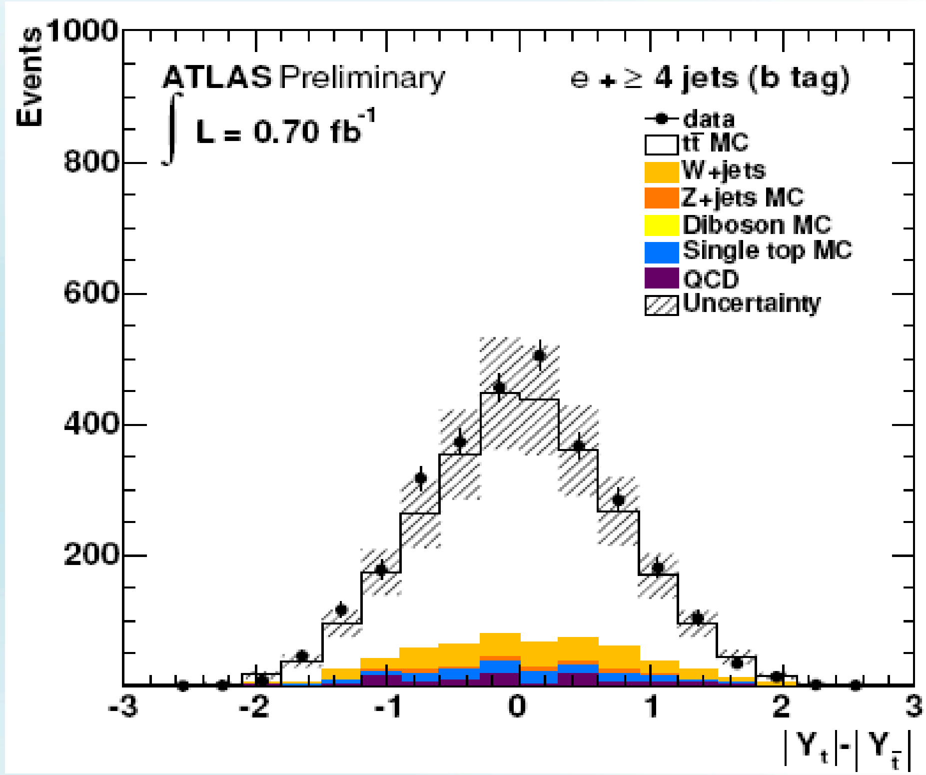
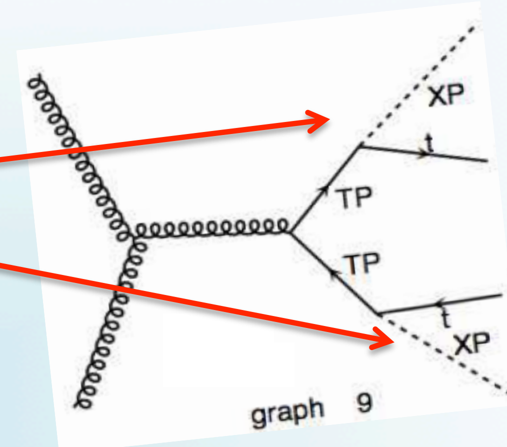


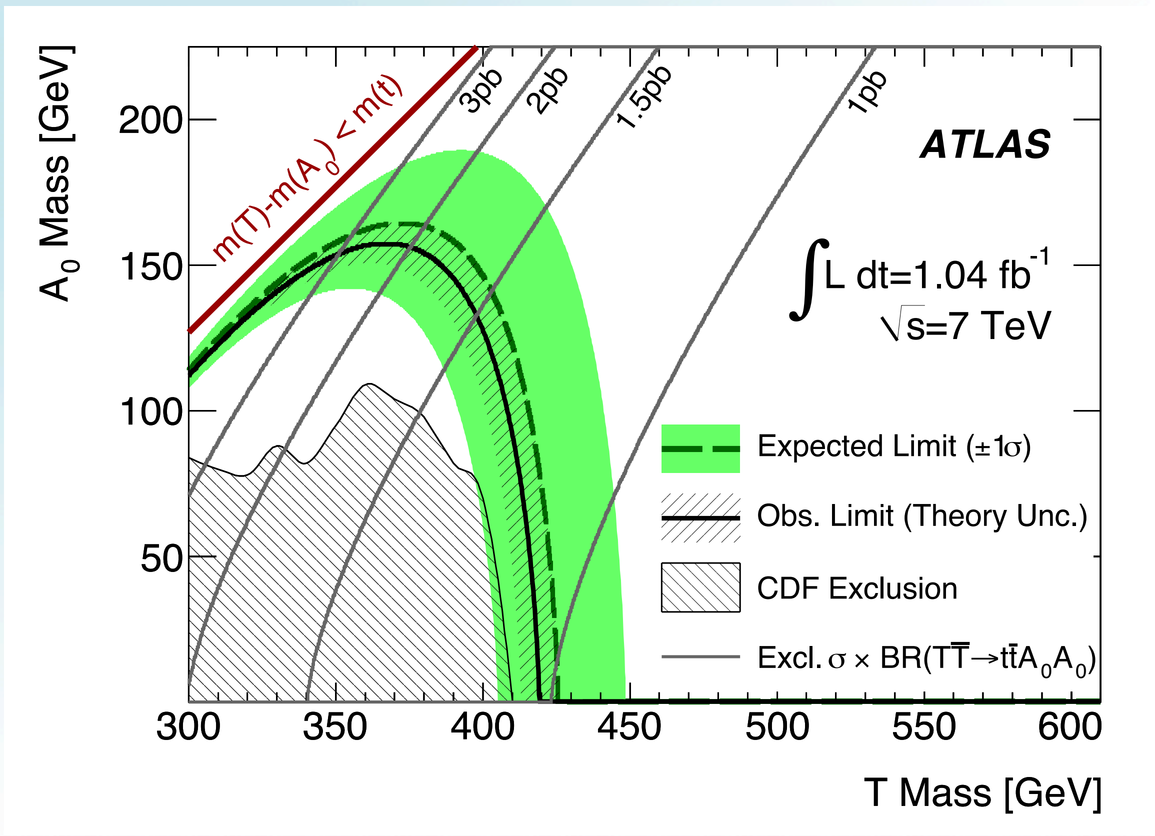
A_C = - 0.024 ± 0.016(stat) ± 0.023(syst)

$t\bar{t}$ + anomalous E_T^{miss}

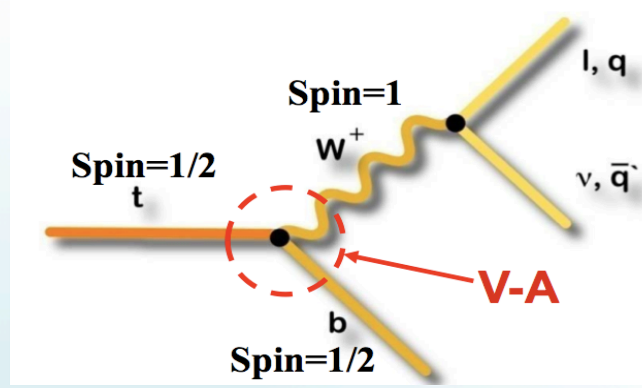
- Search for anomalous E_T^{miss} in ttbar (lepton+jets) events
  - benchmark: TT pair, T→tA_o
    - Ao dark matter candidate
    - Enhanced cross-section due to spin states
  - Signal region:
    - ET^{miss} >100 GeV, m_T>150 GeV; dilepton veto: p_T > 15 GeV, tracks

Alwall, Feng, Kumar *et al.* (2010)
Berger, Cao (2009)



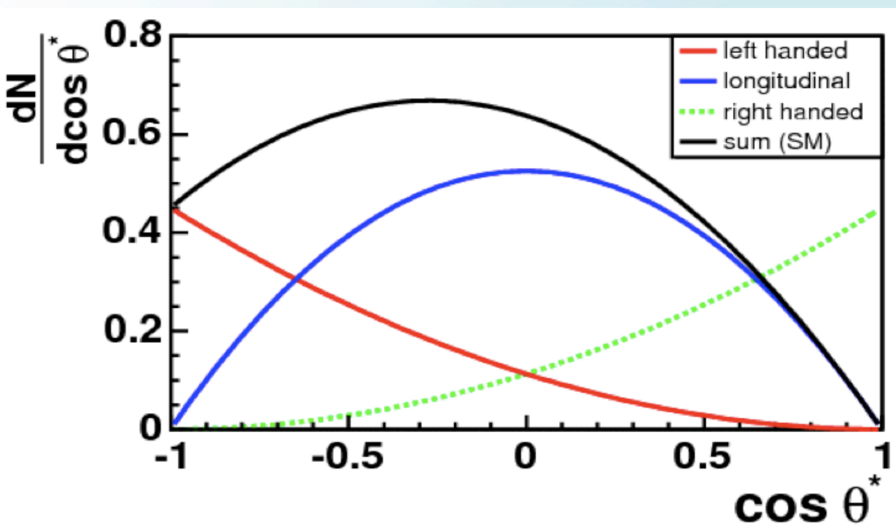


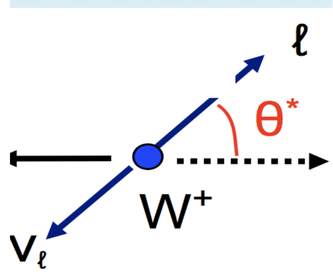
W helicity

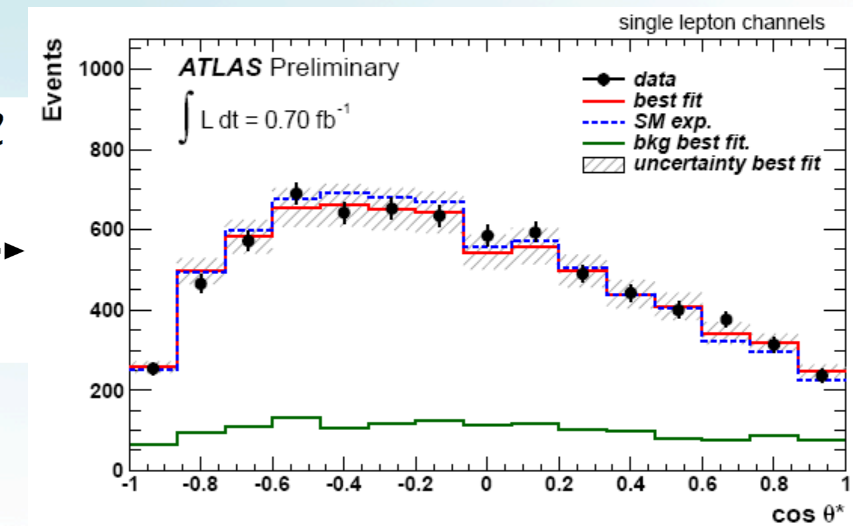


- V-A coupling predicts:
  - $F_o \approx 0.7$ (long. polarization)
  - $F_R \approx 0$ (RH polarization)
  - $F_L \approx 0.3$ (LH polarization)
- Wtb structure probed → set limits on new physics
- Use e+jets and μ+jets channels
  - Can extract directly from cos θ* or unfold to parton level and calculate asymmetry

	Single Lepton	Single+ Dilepton
F_L	0.57 ± 0.07(stat) ± 0.09(sys)	0.25 ±0.08
F_0	0.35 ± 0.04(stat) ± 0.04(sys)	0.75 ±0.08
F_R	0.09± 0.04(stat) ± 0.08(sys)	0 (imposed)







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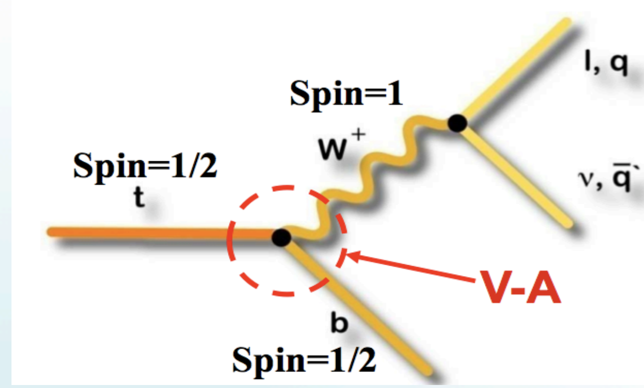

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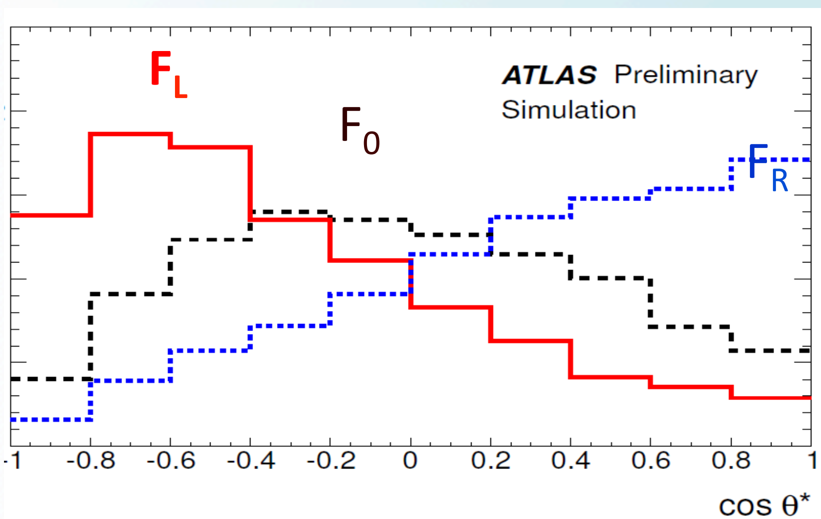
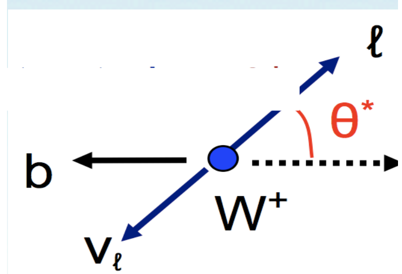
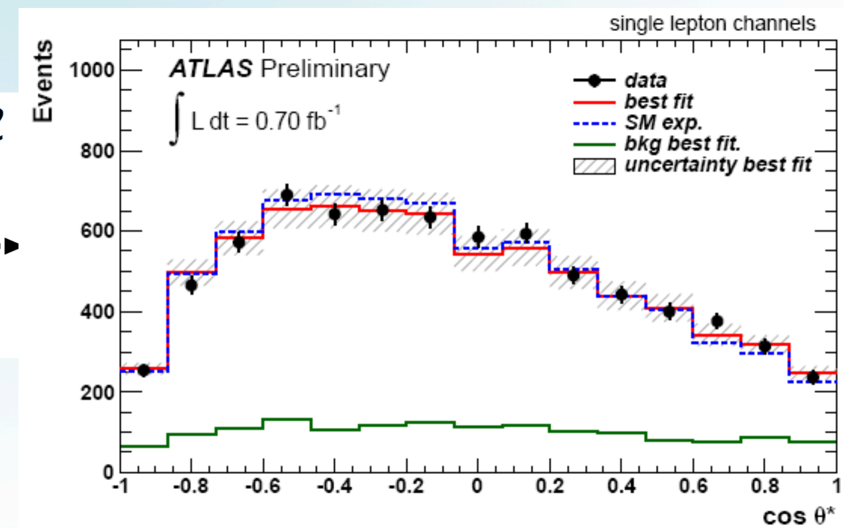


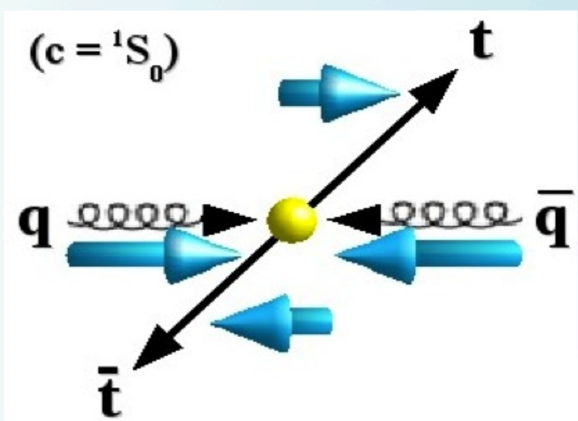




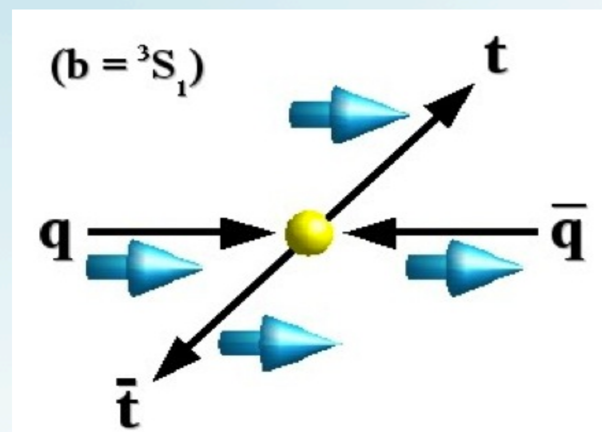
Spin correlations I

- Motivation: test of SM predictions, BSM scenario predicts different correlations
  - complementary to Tevatron measurements: ≠ energy and ≠ dominant production mechanism
- Top and antitop decay hadronizing:
  - polarization is not lost
  - **spin correlation from angular distributions of decay products**
- **SM prediction compared with non correlation hypothesis**

Dominant at LHC



Dominant at Tevatron

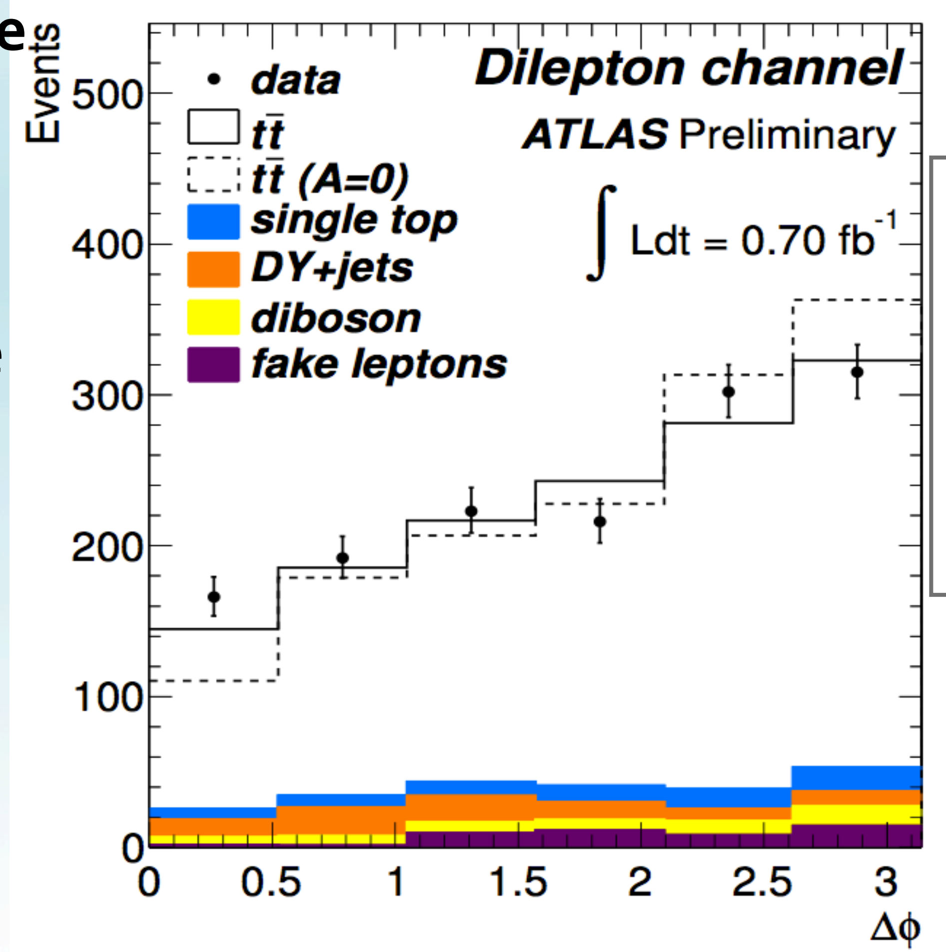


Spin correlations II

- **Dilepton** channel, using **0.70 fb^{-1}**
- $$A = \frac{N_{like} - N_{unlike}}{N_{like} + N_{unlike}} = \frac{N(\uparrow\uparrow) + N(\downarrow\downarrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)}$$
- <u>Observable:</u> **$\Delta\Phi(l^+,l^-)$ in the lab frame**
  - **no need to reconstruct event kinematics**
- no b-tagging
- Main backgrounds : DY+jets and fake leptons
- $\Delta\Phi(l^+,l^-)$ distribution in data is fitted with SM and no-correlation predictions
- Correlation coefficient (A^{SM}=0.32):

A= = $0.34^{+0.15}_{-0.11}$

- Main systematics:
  - MC available statistics
  - signal modelling (MC generator and ISR/FSR)



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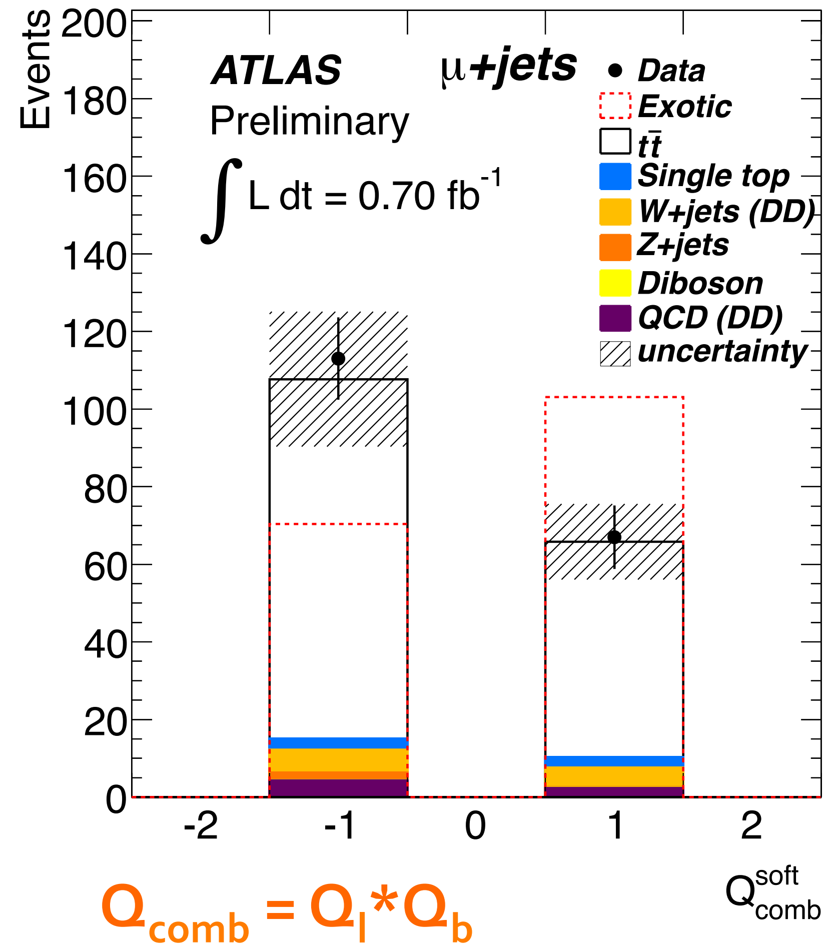
Top quark charge

- Motivation: **exclude an exotic top quark** with a charge -4/3
- L+jets analysis with **0.70 fb^{-1}**
- Crucial points for the analysis:
  - **pair correctly W-boson and b-jet**
  - **measure W boson and b-jet charge**
    - W boson charge from the lepton
- Two techniques:
  - W-b pairing from m(l,b-jets), **b-jet charge = sum of associated tracks charges**
  - W-b pairing using a kinematic fitter, select events with a soft μ inside the b-jet of the leptonic leg: $Q_b = Q_\mu$
- Main systematics: ISR/FSR



$Q_{comb} = Q_l * Q_b$

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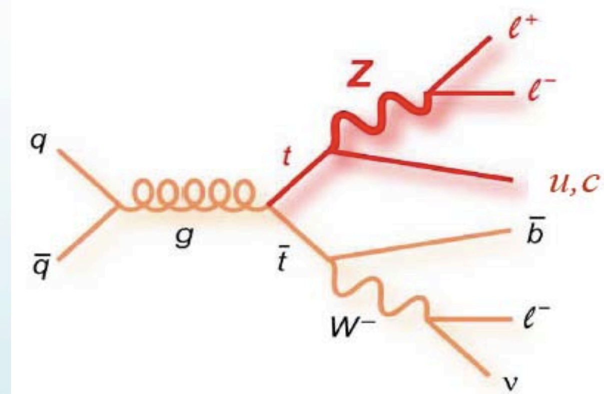
Agreement with SM: exotic top excluded with >5σ combining e/μ channels

NEW

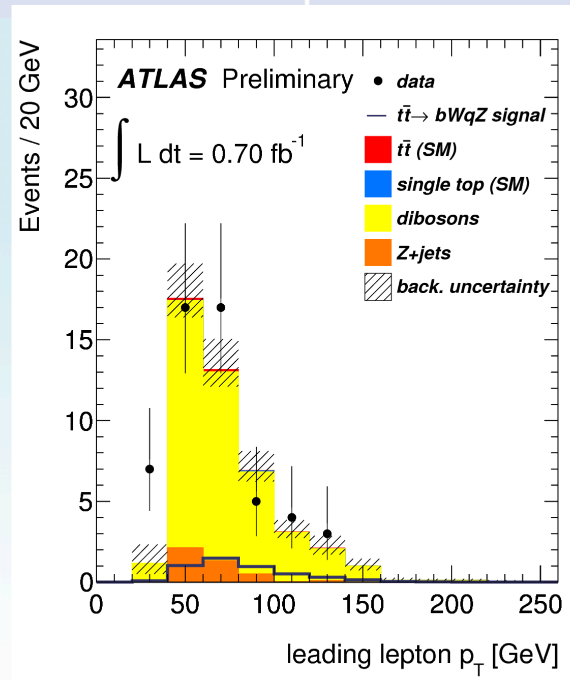
FCNC in decay

- Study top pair events. One of the top decays according to the SM
- Look for **t→Zq** vertex (q =u,c): leptonic W/Z decays to suppress QCD background
- Cut & Count:
  - 3 leptons (> 25 GeV, > 20 GeV, > 15 GeV), two same flavor and OS
  - 2 jets (>30 GeV, >20 GeV), E_T^{miss}>20 GeV
- Main backgrounds:
  - WW, ZW with 3 real isolated leptons: from MC
  - Z+jets, tt (l+jets, dilepton), single top, W+jets and QCD with 1, 2 or 3 fake leptons: DD techniques
- Main systematics: WW, ZW modelling

Observed BR(t→qZ) < 1.1 % @ 95% CL



	BR(t→qZ) (%)
SM prediction:	10^{-12}
new physics:	$10^{-2} - 10^{-8}$
from Tevatron:	< 3.2



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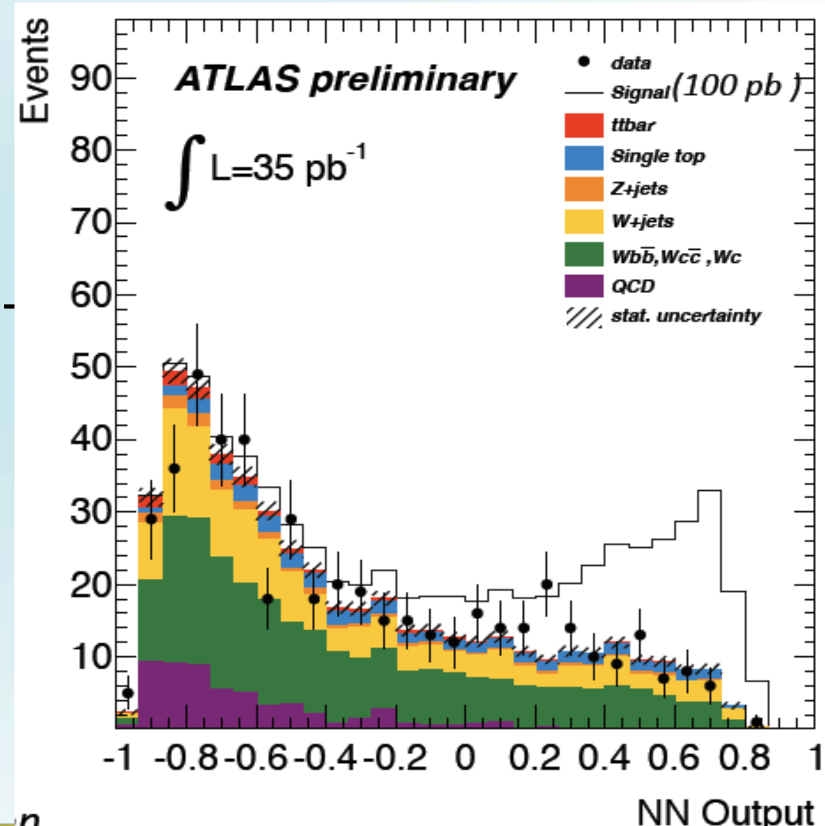
FCNC in production

Process	SM	2HDM	SUSY
$u+g\rightarrow t$	$3.7*10^{-14}$	10^{-4}	$8*10^{-5}$
$c+g\rightarrow t$	$4.6*10^{-12}$	10^{-4}	$8*10^{-5}$

- look for **gq→t vertex**
  - anomalous single top production
- Single lepton Events
  - exactly 1 b-tagged jet
  - exactly 1 lepton (e/μ)
- Neural Network with 13 input variables-binned likelihood ratio
- No excess observed: limit on σ_{qg}*BR(t→Wb)
- Systematics: ISR, JES, HF content in W+jets



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Observed σ_{qg}→t*BR(t→Wb) < 17.3 pb
Expected σ_{qg}→t*BR(t→Wb) < $17.4^{-5.4}_{+8.2}$ pb

New Physics (?)

Resonances I

- Motivation: new resonances that decay predominantly to top quark pair predicted by some BSM models
- Dilepton analysis with **1.04 fb^{-1}** of data
- Goal: **search for excess in the $H_T+E_T^{miss}$ spectrum**
- Signal: KK-gluon in Randall-Sundrum model
- Event selection: no b-tagging request
- Backgrounds:
  - DY+jets and fakes from data
  - SM tt, t, dibosons from MC
- Data are compatible with SM background only hypothesis
- Main systamatics:
  - JES and tt modelling

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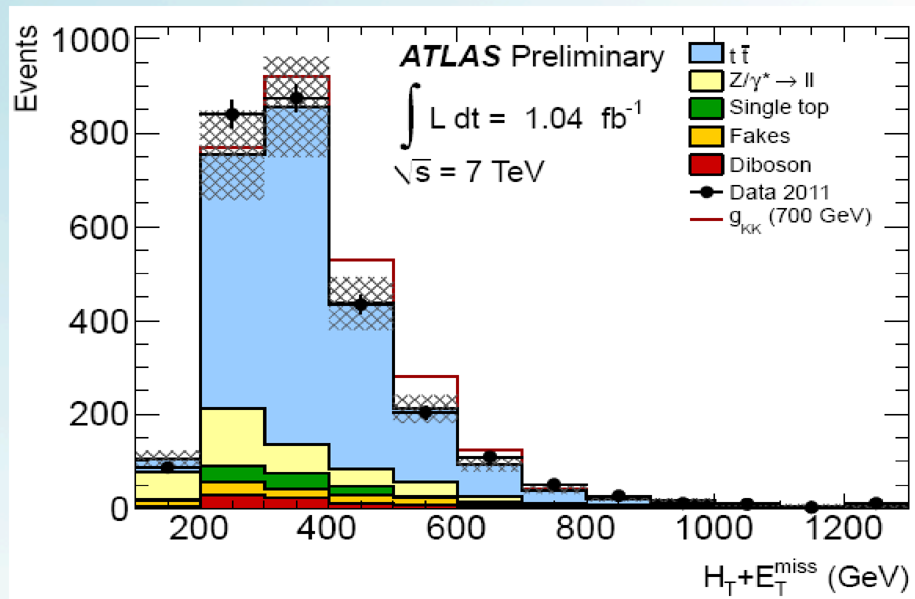
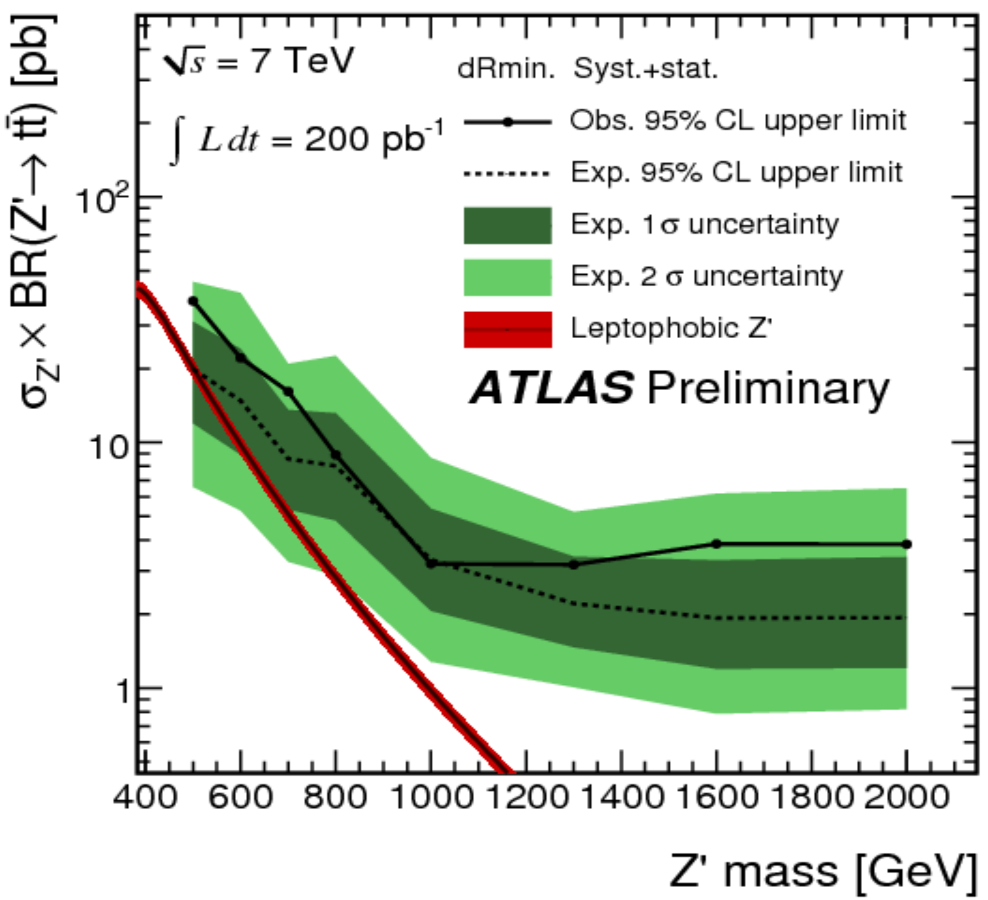
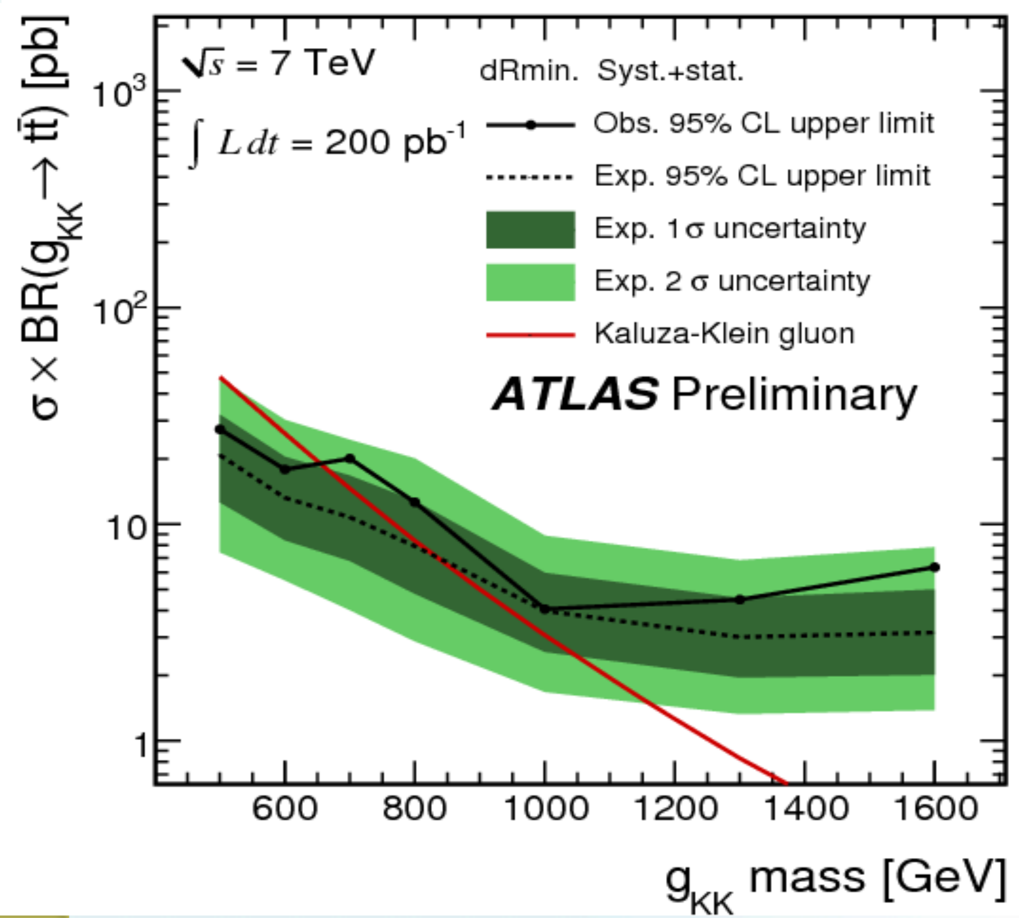


M_{kk} > 0.84 TeV @ 95% CL

Resonances II





For a narrow *Z′*, observed 95% C.L. limits range from ≈38 pb to 3.2 pb for masses from $M_{Z'}$= 500 GeV to 1300 GeV.

In Randall-Sundrum models, KK gluons with masses below 650 GeV excluded at 95% C.L.

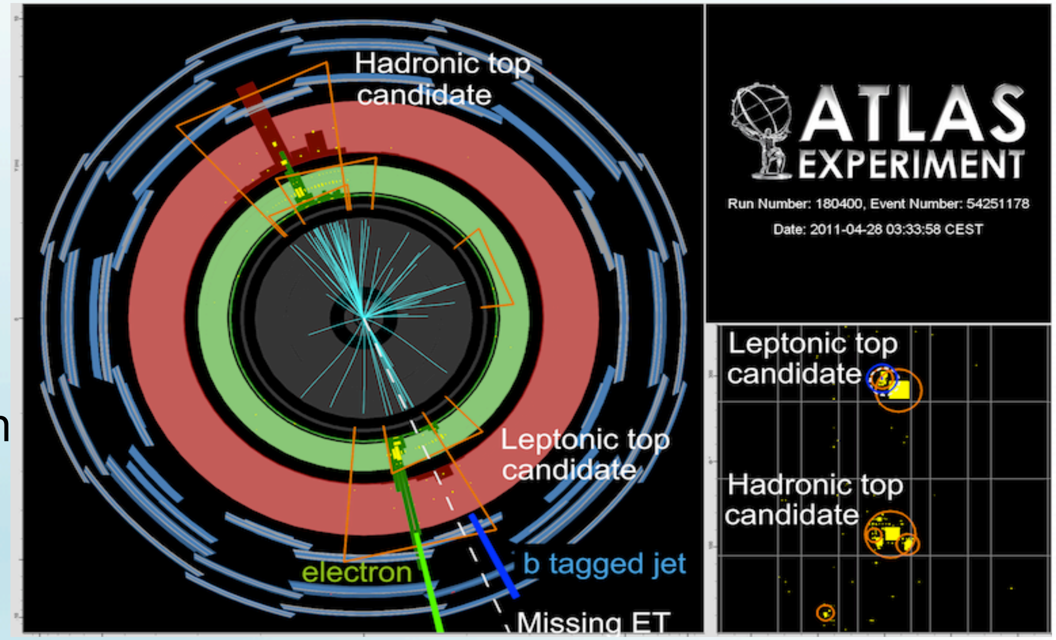
Conclusions

- For most of the studies, 0.7 fb-1 of data analysed
- All results consistent with SM expectation
- Very competitive measurements:
  - σ_{tt} measured in different channels, using 2011 data
    - **up to 7% precision reached**
  - measurement of jet multiplicity to constrain ISR
  - **NEW result: top-antitop + photon cross section**
  - measurements of the main top properties:
    - **NEW result: UPDATE on FCNC measurement**
  - searches for new physics in top events: constraints on the mass of new particles
- Most of them already limited by systematics
  - work ongoing to decrease the various contributions
- Still a lot of 2011 data to be analyzed

In Top Veritas?

Search for high $m_{t\bar{t}}$

- In many new physics models top plays a special role
  - **Narrow resonance**: leptophobic topcolor Z' as benchmark model
  - **Wide resonance**: a Kaluza-Klein gluon g_{KK}, which appears in Randall-Sundrum models
- $m_{t\bar{t}}$ from 3 or 4 jets, e/μ, and ν
  - ΔR_{min} variant (4 highest p_T jets considered, jet removed if too far from other objects and has too high mass)
- Normalization uncertainties
  - W (35%), diboson (5%), QCD in e (30%) and μ (50%) channels
- Shape uncertainties
  - b-tag (11%), JES (9%), ISR/FSR(7%)



	Electron channel	Muon channel
$t\bar{t}$	723.8	987.6
Single top	35.7	50.3
W+jets	92.7	172.3
Z+jets	5.9	8.0
Diboson	1.6	2.3
Total MC Background	859.7	1220.5
QCD Background	34.8	104.8
Total Expected	894.5	1325.3
Data observed	935	1396
Z', m = 500 GeV	15.4	21.4
g_{KK}, m = 700 GeV	68.3	92.9

Other new physics searches

- Search for resonances in m(top-antitop) spectrum performed in l+jets ch. with 200 pb^{-1}: **limits for a Z′ boson:**
  - 95% C.L. limits on σxBR(Z′ tt): 38 at $m_{Z'}$=500 GeV and 3.2 at $m_{Z'}$=1300 GeV
- Other new physics searches involving top quark reported in Nenad Vranjes talk:
  - tt + E_T^{miss} searches:
    - data are found to be consistent with SM expectations. Limits at 95% CL put on new particles masses and cross sections
  - same sign top search:
    - no observation of same sign tops, upper limits on flavour-changing *Z*′ boson cross-section
  - …

m_{top} from $\sigma_{t\bar{t}}$

- Use most accurate measurement
  - Multivariate analysis with b-tag
- Exploit dependence of σ_{tt} from m_{top}
  - Assume $m_{top}^{MC} = m_{top}^{pole}$
- m_{top} from combined uncorrelated th. and exp. likelihood: the max determines the extracted m_{top}^{pole}
  - fit performed for 3 theoretical calculations
- 13% uncertainty on σ_{tt}
  ~ 5 GeV uncertainty on m_{top}
- Default analysis → NNLO Langenfeld
  - (Phys. Rev. D80 (2009) 054009)

$m_{top} = 166.4^{+7.8}_{-7.3}$ GeV