The Abdus Salam International Centre for Theoretical Physics

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Beyond the Standard Model: Results with the 7 TeV LHC Collision Data

19 - 23 September 2011

New Physics Searches Involving Top Quarks with the ATLAS Detector

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New Physics Searches Involving Top Quarks with the ATLAS Detector

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on behalf of the ATLAS Collaboration

Beyond the Standard Model:
Results with the 7 TeV LHC Collision Data
ICTP, Trieste, 19-23 September 2011

Outline:

- The top quark and BSM physics
- New physics in top production and decay
- Searches for top-like BSM signatures

Results based on:

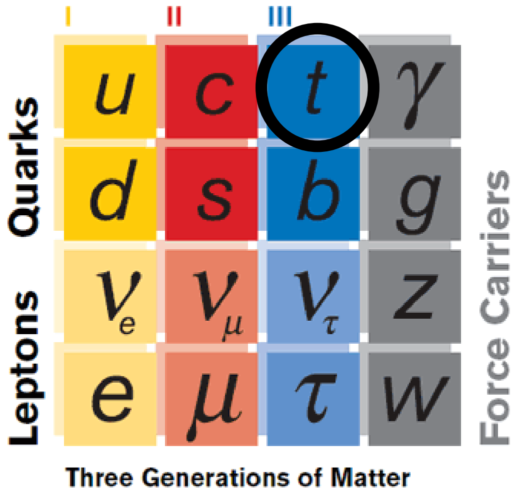
- 2010 ATLAS data: $\int Ldt \sim 35\ \mathrm{pb}^{-1}$
- 2011 ATLAS data: $\int Ldt \sim 1\ \mathrm{fb}^{-1}$

`https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults`

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

The top quark

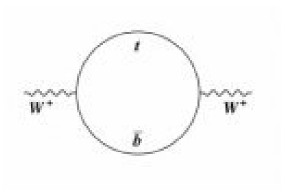
- Top quark completes the 3 family structure of the SM
  - top is the weak-isospin partner of the *b*-quark
  - spin = $1/2$
  - charge = $+2/3\ |e|$



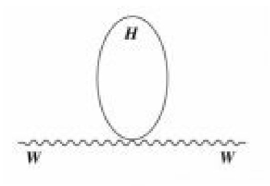
- Top quark is the heaviest known quark ($m_t = 173.2 \pm 0.9$ GeV, CDF+ D0, arXiv:1107.5255)
- Top decays (almost exclusively) through $t \rightarrow bW$
  $BR(t \rightarrow sW) \leq 0.18\%$, $BR(t \rightarrow dW) \leq 0.02\%$
- $\Gamma_t^{SM} = 1.42$ GeV
  (including m_b, m_W, α_s, EW corrections)
  - Λ_{QCD}^{-1}=(100 MeV)$^{-1}$=10^{-23}s (hadronization time)
  - $\tau_t \ll 10^{-23}$ s
    $\Rightarrow$ top decays before hadronization

The top quark as a probe for beyond SM physics

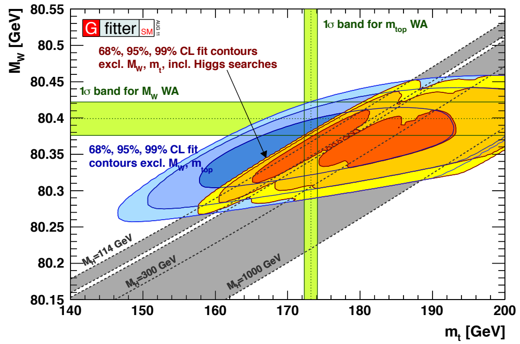
- Large mass of the t-quark:
  - $\lambda_t = \sqrt{2} m_t / v \sim 1$ ☞ special role in EWSB?
  - top and W masses constrain the Higgs mass



$\Delta m_W \propto m_t^2$

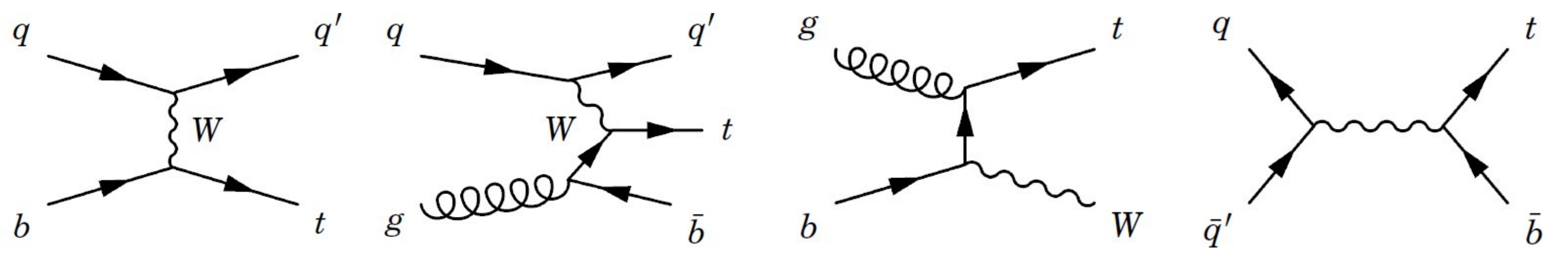


$\Delta m_W \propto \ln m_H$



- BSM physics often has consequences in the top sector:
  - $t\bar{t}$ and single top production can be affected by BSM models
  - *Wtb* vertex: can have a BSM structure
  - rare top decays: BSM models can increase the BR of t-quark decays via FCNC
  - Exotic Higgs Bosons: large coupling to the top
  - Incorporate Gravity using Extra Dimensions: many models predict new states with strong coupling to the top
  - 4th generation quarks: often decay to t-quarks or look like a heavy t
  - ...

Single top production at LHC

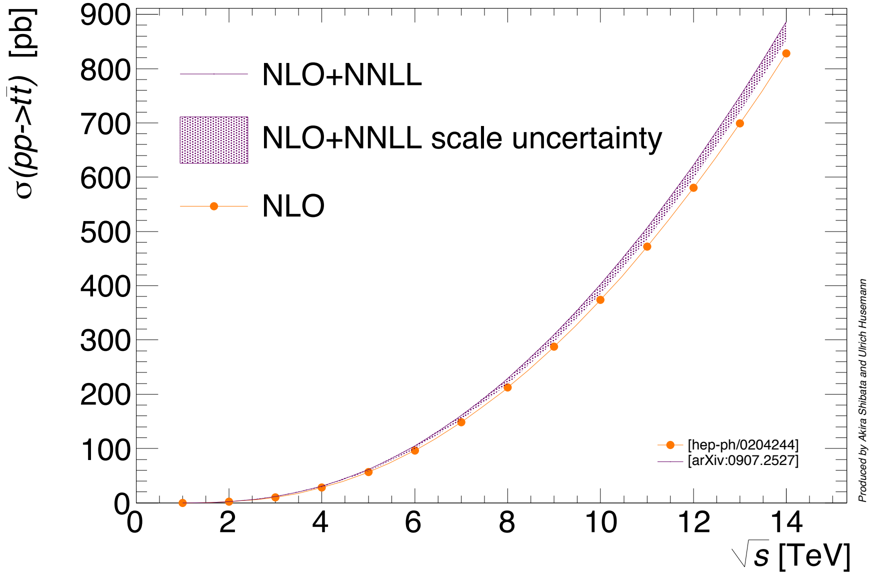


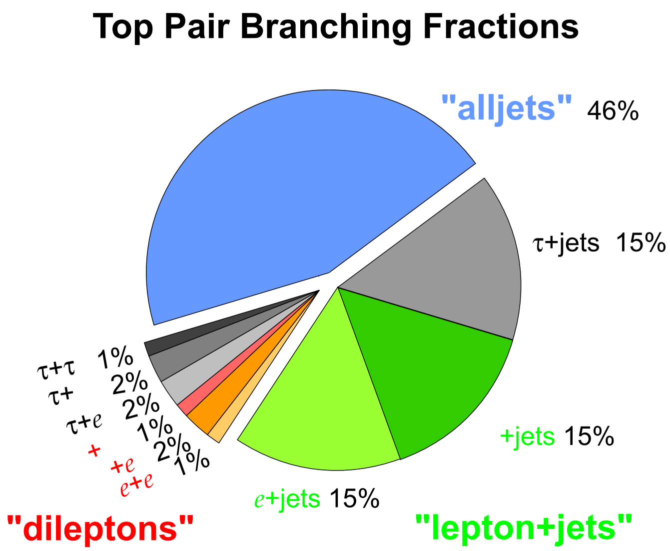
Channel	SM prediction	ATLAS measurement
s	4.6 ± 0.3 pb	< 26.5 pb (ATLAS-CONF-2011-118)
Wt	$15.7^{+1.3}_{-1.4}$ pb	< 39 pb (ATLAS-CONF-2011-104)
t	$64.6^{+3.3}_{-2.6}$ pb	90^{+32}_{-22} pb (ATLAS-CONF-2011-101)

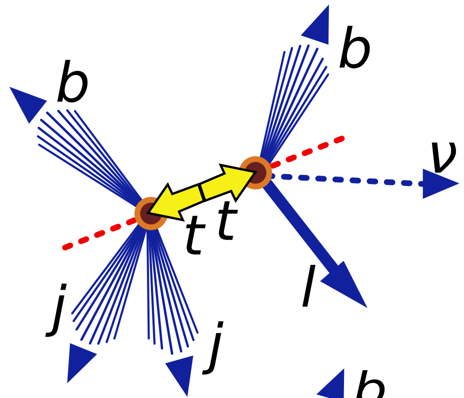
(see talk by Muhammad Alhroob for details)

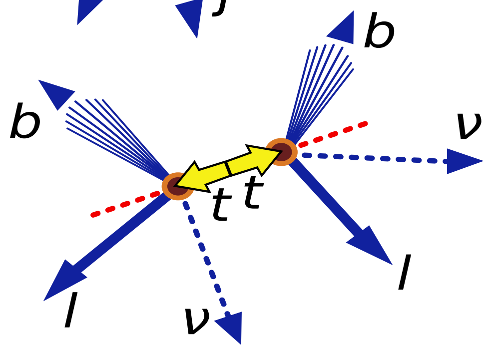
☞ Good agreement with SM expectation found

$t\bar{t}$ production at the LHC





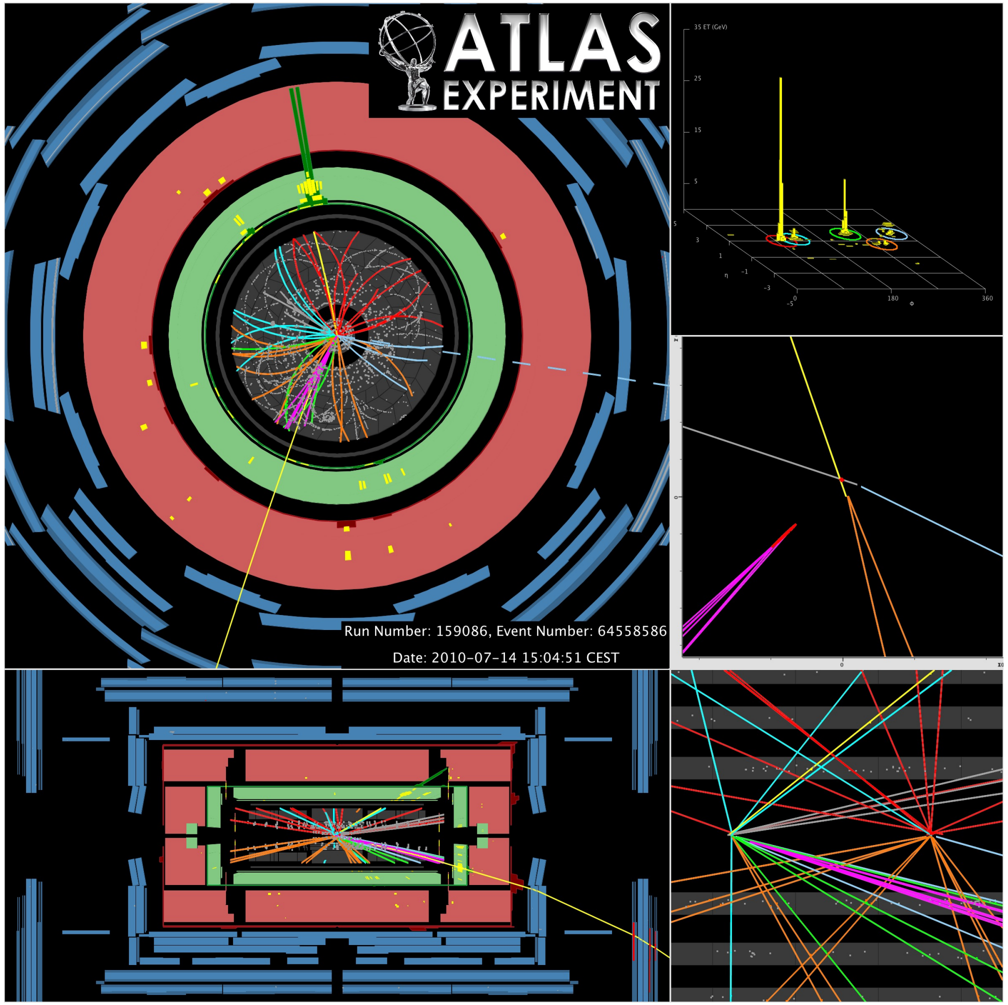




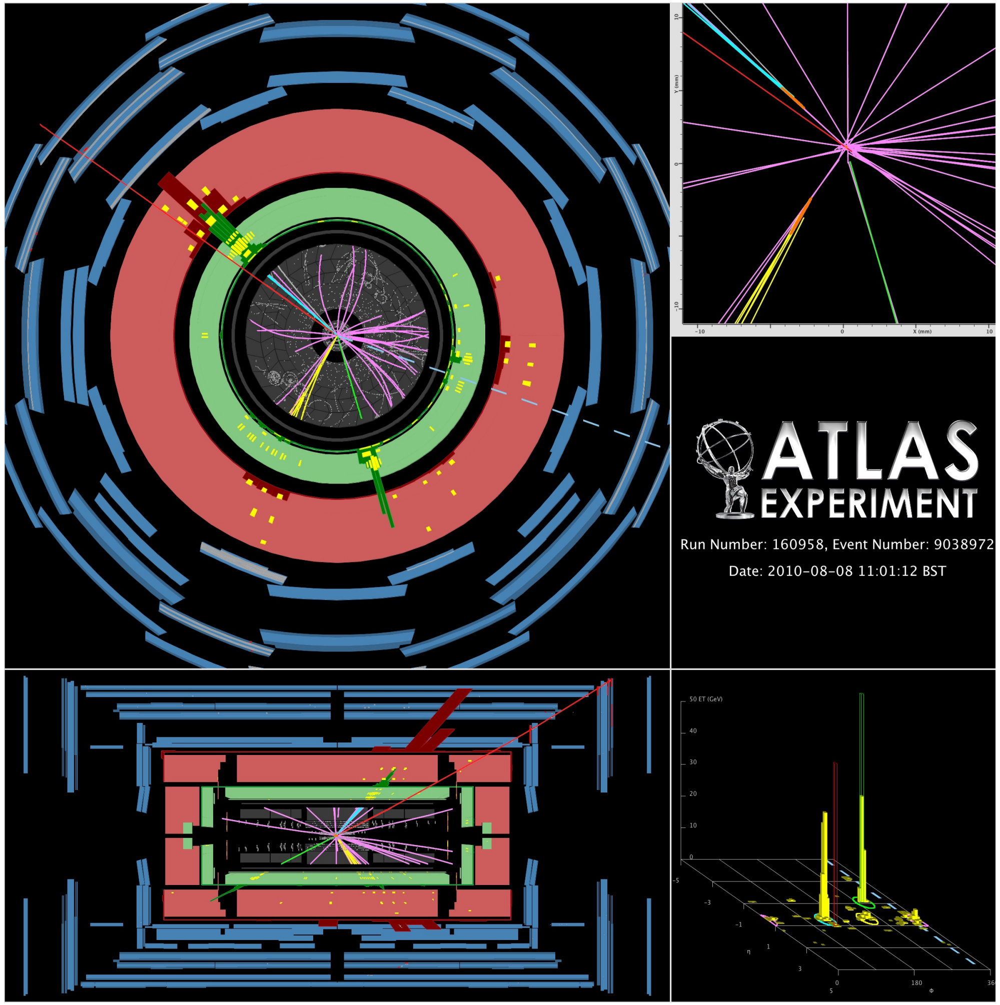
- $\sigma(t\bar{t})$ @ 7 TeV $\sim 164.6^{+11.4}_{-15.7}$ pb (arXiv:0907.2527)
- lepton+jets topology:
  $BR(t\bar{t} \to bq\bar{q}'\bar{b}\ell\nu;\ \ell = e^{\pm}, \mu^{\pm}, \tau^{\pm}) \sim 44\%$
- dileptonic topology:
  $BR(t\bar{t} \to b\bar{b}\ell\nu\ell\nu;\ \ell = e^{\pm}, \mu^{\pm}, \tau^{\pm}) \sim 10\%$

$t\bar{t}$ production at the LHC: events seen by ATLAS

(semileptonic e+jets w/btag)

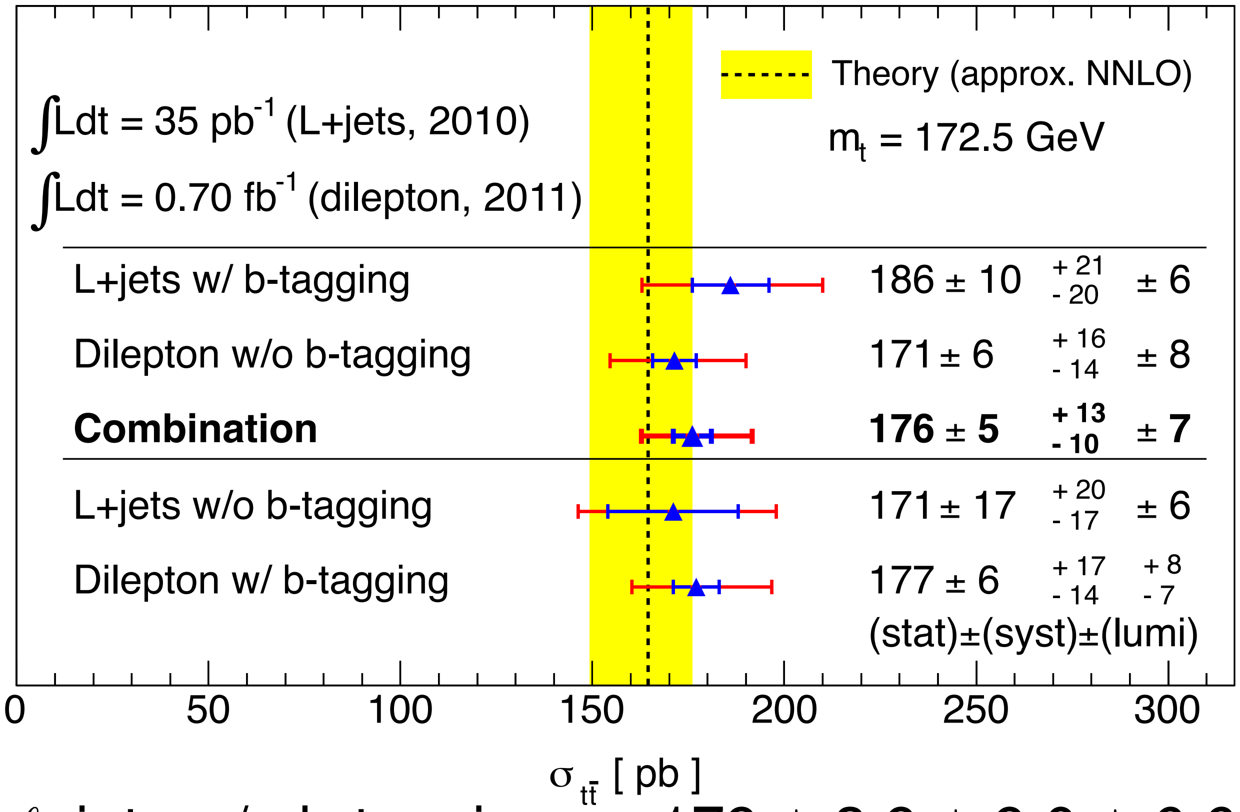


(dileptonic $e\mu$+jets w/2 btag)



Measurement of $\sigma(t\bar{t})$

ATLAS Preliminary, $\sqrt{s} = 7$ TeV (ATL-CONF-2011-108)



ℓ+jets w/o b-tagging $\quad 179 \pm 3.9 \pm 9.0 \pm 6.6$

$\int Ldt = 0.7$ fb^{-1} $\quad$ (ATL-CONF-2011-121)

(see talk by Muhammad Saleem for details)

☞ Good agreement with SM expectation found

Search for $t\bar{t}$ resonances

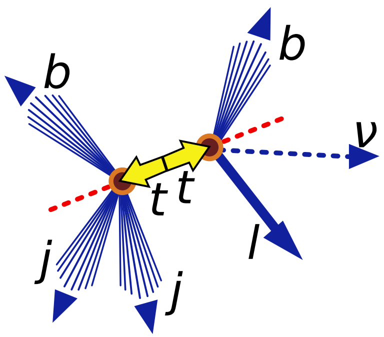
☞ Standard $t\bar{t}$ selection in ℓ+jets and dilepton channels

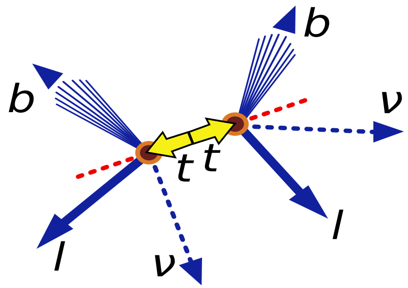
ℓ+jets channel (ATLAS-CONF-2011-087)

- isolated lepton (e or μ)
- missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$)
- 4 or more jets (anti-k_T, $\Delta R = 0.4$)
- at least 1 b-tagged jet

dilepton channel (ATLAS-CONF-2011-123)

- 2 isolated leptons (ee, $\mu\mu$ or $e\mu$)
- ee, $\mu\mu$: $m_{\ell\ell}$ outside m_Z window
- $e\mu$: large scalar sum of p_T of all hard objects in the event (H_T)
- $E_{\mathrm{T}}^{\mathrm{miss}}$
- 2 or more jets

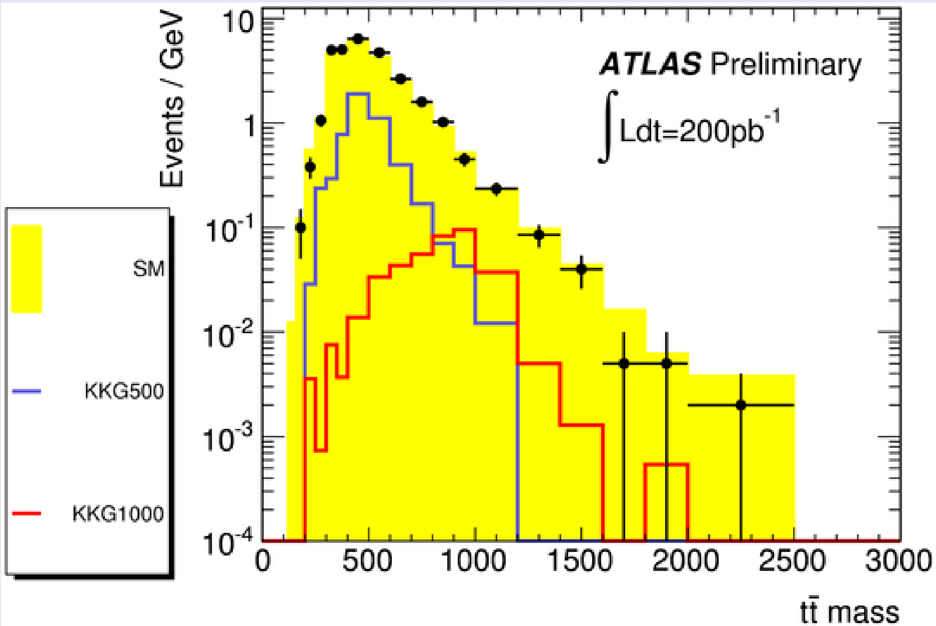




Search for $t\bar{t}$ resonances

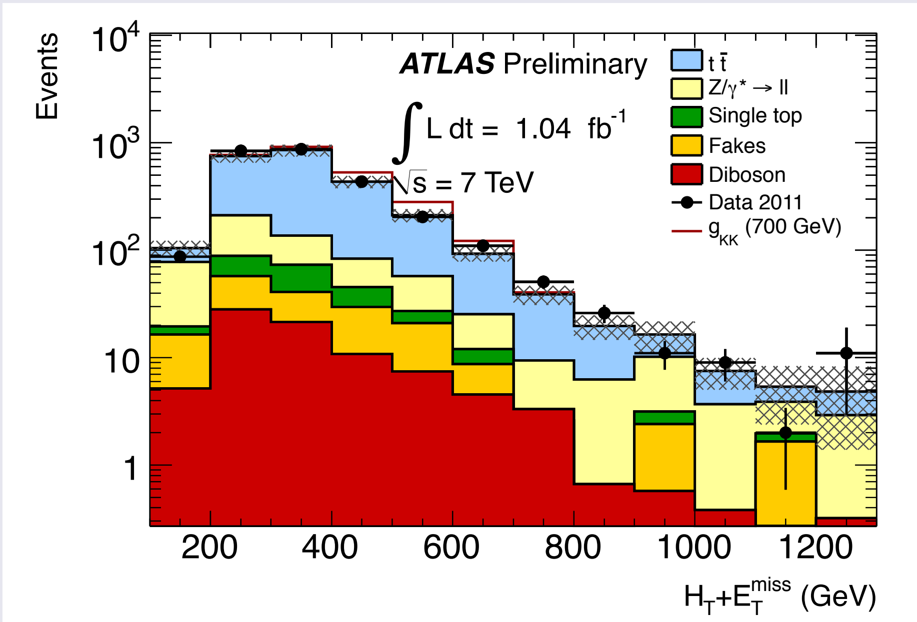
ℓ+jets channel

search for bumps in $m_{t\bar{t}}$
(BumpHunter, arXiv:1101.0390
see Georgios Choudalakis talk)



dilepton channel

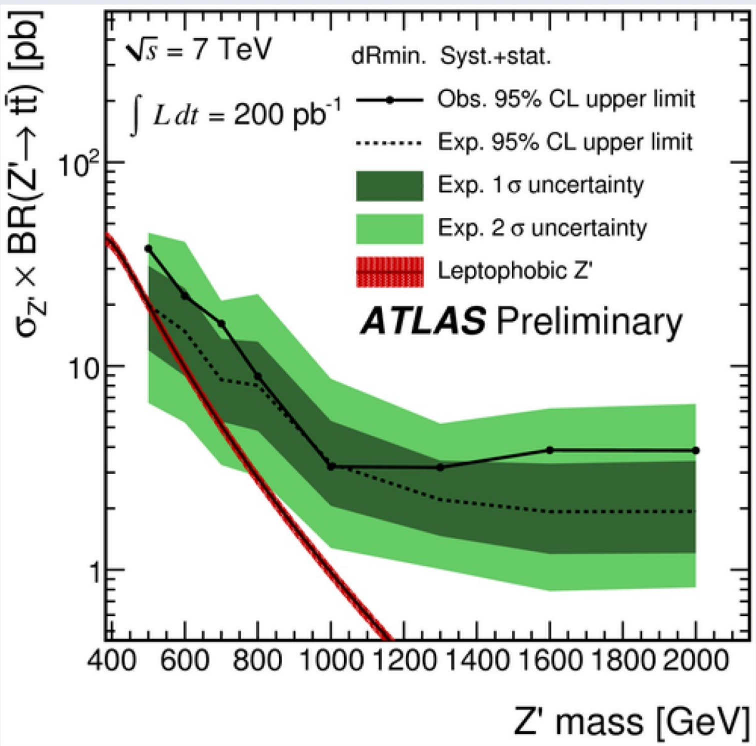
use $H_T + E_T^{\mathrm{miss}}$ variable



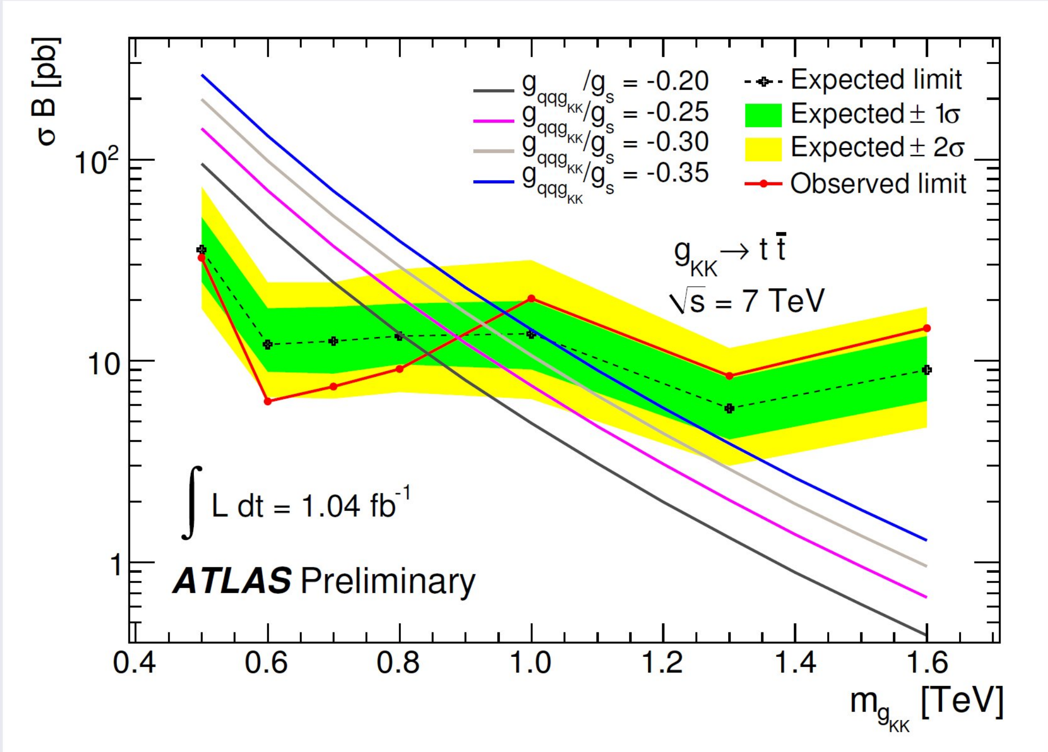
☞ Data in agreement with the SM expectation in both channels

Search for $t\bar{t}$ resonances

l+jets



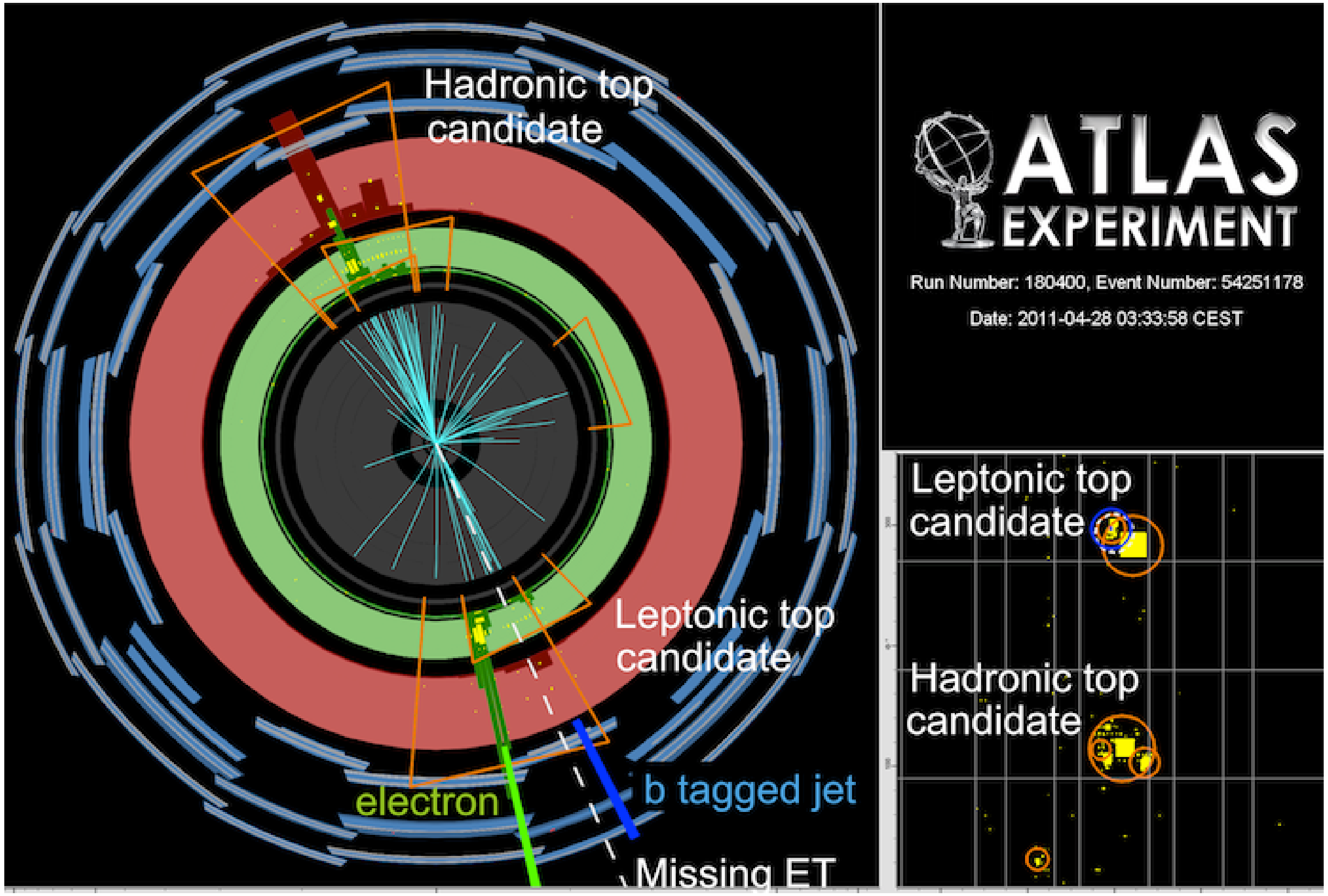
dileptons



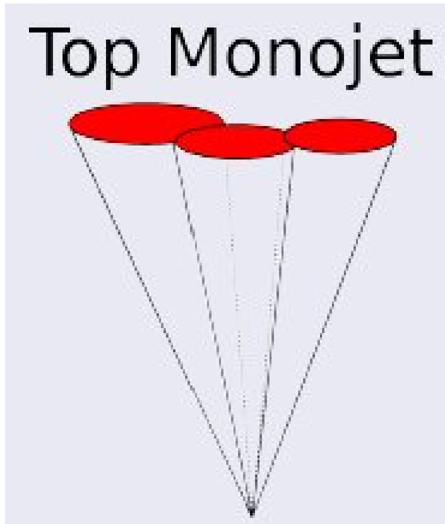
- ℓ+jets channel: limits set on narrow Z'-like decaying into $t\bar{t}$
  ☞ no exclusion yet for benchmark (topcolor-assisted technicolor) Z' model (see talk by Nicolas Berger)
- dilepton channel: limits set on broader g_{KK}-like resonances
  ☞ $m_{g_{KK}} < 0.84$ TeV excluded at 95% CL

Search for $t\bar{t}$ resonances: boosted objects

- For higher regions of p_T^t or $m_{t\bar{t}}$ the top decay products are highly boosted and can be reconstructed as only one jet
- Understanding boosted objects is very important for top physics and searches for new physics



$m_{t\bar{t}} = 1602$ GeV

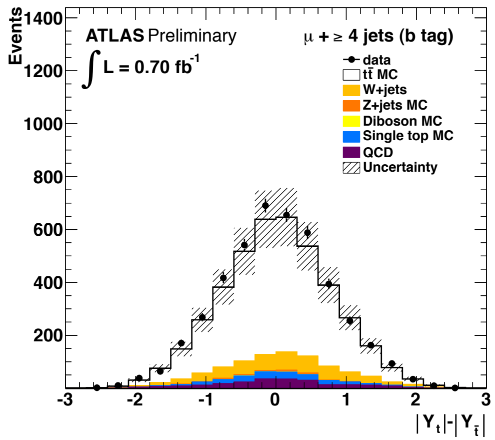


Charge asymmetry in $t\bar{t}$ production

- At LO $t\bar{t}$ production is symmetric under charge conjugation in the SM (small asymmetry expected at NLO)
- Several BSM processes can alter this asymmetry, either with abnormal vector or axial vector couplings or via interference with the SM

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

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



Distributions are unfolded to parton level

$$A_C = -0.009 \pm 0.023\ (\text{stat}) \pm 0.032\ (\text{syst})\ (e\text{+jets})$$
$$A_C = -0.028 \pm 0.019\ (\text{stat}) \pm 0.022\ (\text{syst})\ (\mu\text{+jets})$$
$$A_C = -0.024 \pm 0.016\ (\text{stat}) \pm 0.023\ (\text{syst})\ (\text{comb})$$

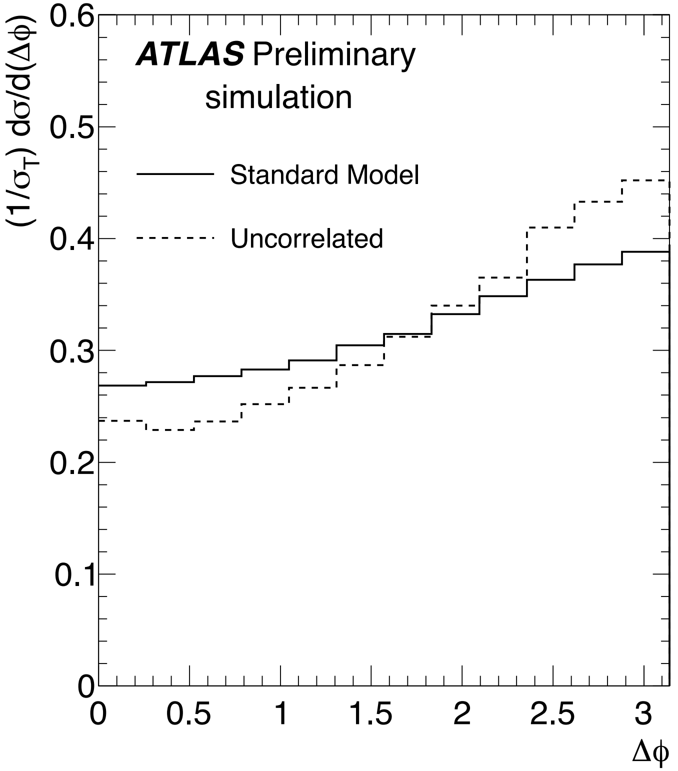
(ATLAS-CONF-2011-106, see talk by Rachik Soualah for details)

SM expectation (MC@NLO): $A_C = 0.006$

☞ No evidence for new physics found

$t\bar{t}$ spin correlations

- While t-quark pairs produced at hadron colliders are unpolarized, their spins are correlated
- Different BSM scenarios predict different production and decay dynamics of the top quark, which could be detected by measuring the $t\bar{t}$ spin correlations
- In the dilepton channel $\Delta\phi_{\ell\ell}$ can distinguish the SM expectation from a no-correlation scenario



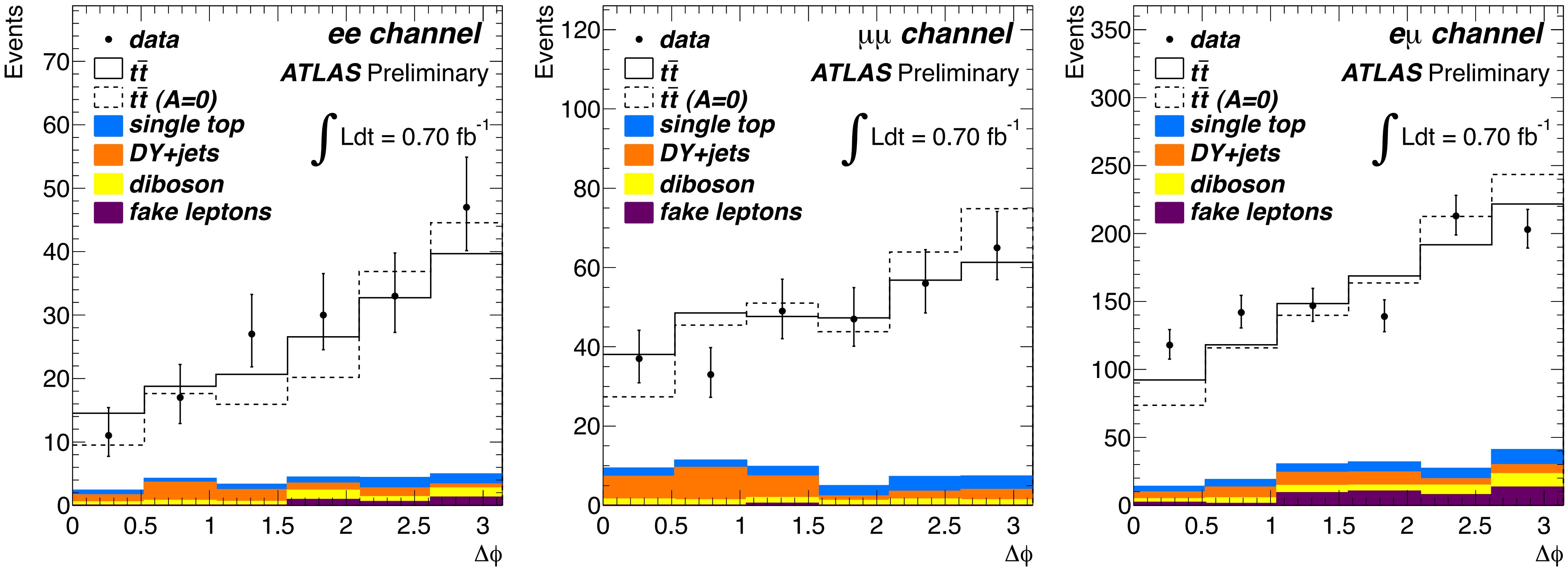
[Phys. Rev D81 (2010) 074024]

$$A = \frac{N_{like} - N_{unlike}}{N_{like} + N_{unlike}}$$

where N_{like} (N_{unlike}) are the number of events where t and $\bar{t}$ spins are aligned (anti-aligned)

$t\bar{t}$ spin correlations

(ATLAS-CONF-2011-117)



- fit done with 2 templates: SM spin correlation (f^{SM}) and uncorrelated hypothesis (f^{UC})
- $f^{SM} + f^{UC} = 1$

$t\bar{t}$ spin correlations

- Different spin basis can be defined; in the SM: [Phys. Lett. B609 (2005) 271]
  - helicity basis: $A^{SM}_{helicity} = 0.32$
  - maximal basis: $A^{SM}_{maximal} = 0.44$
- Considering A^{SM} in a particular basis, the measured spin correlation coefficient can be obtained:

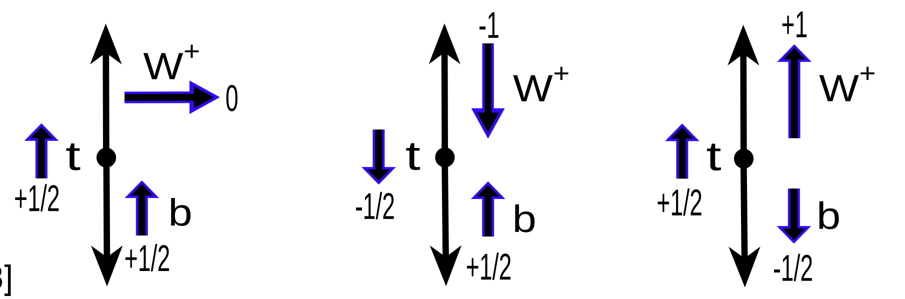
$$\boxed{A^{measured} = A^{SM} \cdot f^{SM}}$$

Channel	f^{SM}	$A_{helicity}$	$A_{maximal}$
e^+e^-	0.89 ± 0.40 (stat) ± 0.44 (syst)	0.28 ± 0.13 (stat) ± 0.14 (syst)	0.39 ± 0.18 (stat) ± 0.19 (syst)
$\mu^+\mu^-$	0.67 ± 0.37 (stat) $^{+0.50}_{-0.30}$ (syst)	0.22 ± 0.12 (stat) $^{+0.16}_{-0.10}$ (syst)	0.30 ± 0.16 (stat) $^{+0.22}_{-0.13}$ (syst)
$e^\pm\mu^\mp$	1.46 ± 0.33 (stat) ± 0.51 (syst)	0.47 ± 0.11 (stat) ± 0.16 (syst)	0.64 ± 0.15 (stat) ± 0.23 (syst)
combination	1.06 ± 0.21 (stat) $^{+0.40}_{-0.27}$ (syst)	0.34 ± 0.07 (stat) $^{+0.13}_{-0.09}$ (syst)	0.47 ± 0.09 (stat) $^{+0.18}_{-0.12}$ (syst)

☞ In agreement with the SM expectation

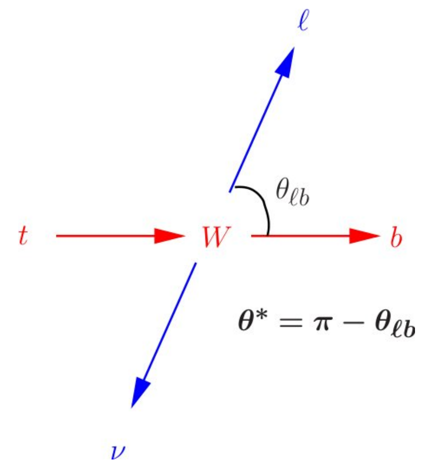
W polarisation in $t \to bW$ decays (ATLAS-CONF-2011-122)

[PRD81 (2010) 111503]



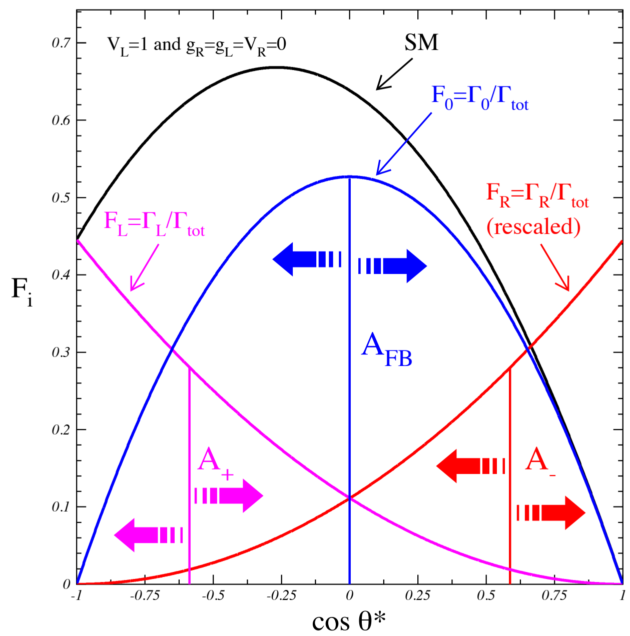
longitudinal W — left-handed W — right-handed W

SM (NNLO): $F_0 = 0.687$ — $F_L = 0.311$ — $F_R = 0.0017$



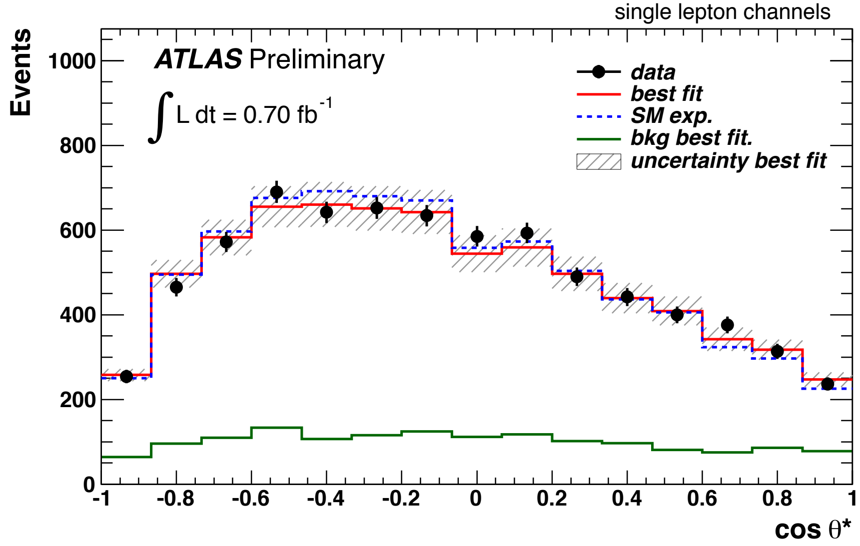
$$\frac{1}{N}\frac{\mathrm{d}N}{\mathrm{d}\cos\theta^*} = \frac{3}{2}\left[F_0\left(\frac{\sin\theta^*}{\sqrt{2}}\right)^2 + F_L\left(\frac{1-\cos\theta^*}{2}\right)^2 + F_R\left(\frac{1+\cos\theta^*}{2}\right)^2\right]$$

- ☞ fit of the $\cos\theta^*$ using templates
- ☞ evaluation of angular asymmetries
- ☞ BSM structure of the *Wtb* vertex changes *W* helicity fractions and angular asymmetries



W polarisation in $t \to bW$ decays (ATLAS-CONF-2011-122)

☞ ℓ+jets and dilepton channels



Effective Wtb vertex from dim-6 operators

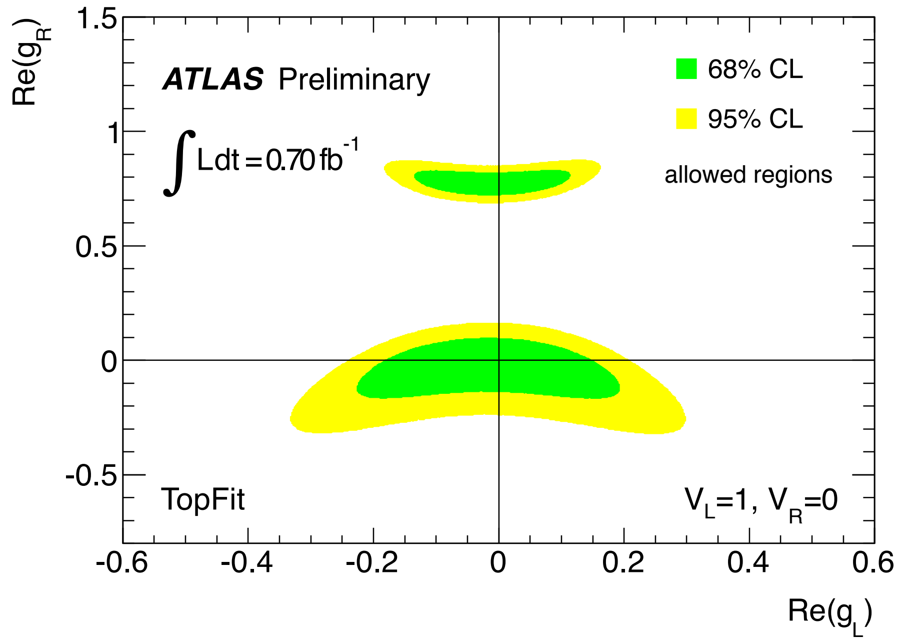
$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\,\gamma^{\mu}\,(V_L P_L + V_R P_R)\,t\,W^{-}_{\mu}$$
$$-\frac{g}{\sqrt{2}}\bar{b}\,\frac{i\sigma^{\mu\nu} q_{\nu}}{M_W}\,(g_L P_L + g_R P_R)\,t\,W^{-}_{\mu}$$

$V_L \equiv V_{tb} \sim 1$ (within SM)

$V_R, g_R, g_L \Rightarrow$ anomalous couplings

	templates ℓ+jets	templates dilepton	asymmetries all
F_0	0.57 ± 0.11	0.75 ± 0.08	0.70 ± 0.10
F_L	0.35 ± 0.06	0.25 ± 0.08	0.31 ± 0.07
F_R	0.09 ± 0.09	fixed to 0	-0.01 ± 0.04

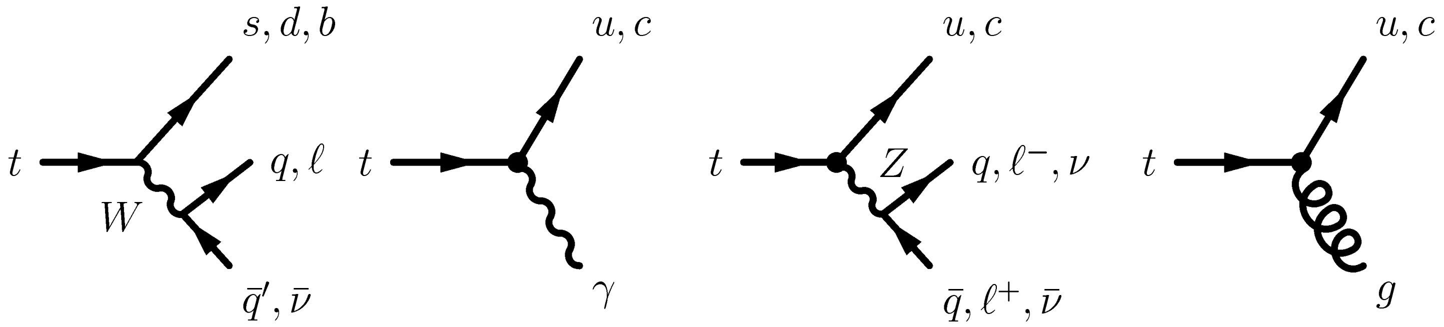
$$A_+ = 0.54 \pm 0.04$$
$$A_- = -0.85 \pm 0.02$$



☞ No evidence for BSM physics

Search for FCNC

Theoretical predictions for the BR of FCNC top quark decays



Process	SM	QS	2HDM	FC 2HDM	MSSM	$\not{R}$ SUSY	TC2
$t \to u\gamma$	3.7×10^{-16}	7.5×10^{-9}	—	—	2×10^{-6}	1×10^{-6}	—
$t \to uZ$	8×10^{-17}	1.1×10^{-4}	—	—	2×10^{-6}	3×10^{-5}	—
$t \to ug$	3.7×10^{-14}	1.5×10^{-7}	—	—	8×10^{-5}	2×10^{-4}	—
$t \to c\gamma$	4.6×10^{-14}	7.5×10^{-9}	$\sim 10^{-6}$	$\sim 10^{-9}$	2×10^{-6}	1×10^{-6}	$\sim 10^{-6}$
$t \to cZ$	1×10^{-14}	1.1×10^{-4}	$\sim 10^{-7}$	$\sim 10^{-10}$	2×10^{-6}	3×10^{-5}	$\sim 10^{-4}$
$t \to cg$	4.6×10^{-12}	1.5×10^{-7}	$\sim 10^{-4}$	$\sim 10^{-8}$	8×10^{-5}	2×10^{-4}	$\sim 10^{-4}$

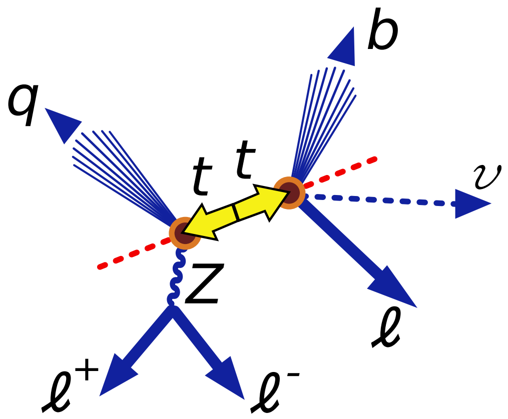
[Acta Phys. Pol. B35 (2004) 2695]

- In the SM flavour changing neutral currents (FCNC) are forbidden at tree level and much smaller than the dominant decay mode ($t \to bW$) at one loop level
- BSM models predict higher BR for top FCNC decays
  ☞ probe for new physics

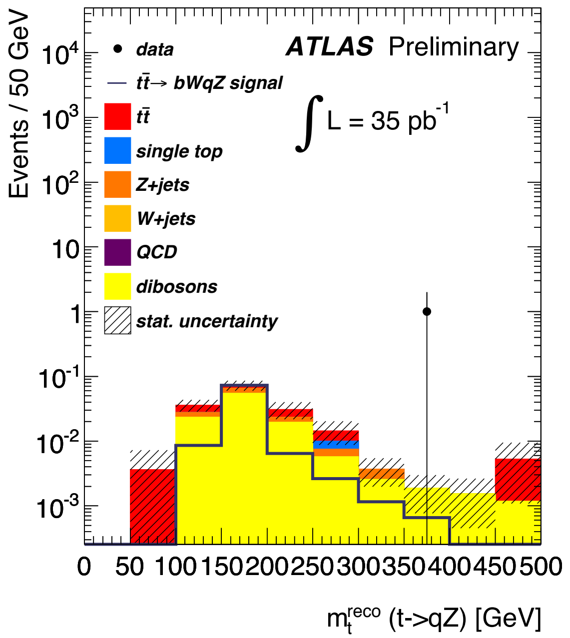
Search for FCNC (ATLAS-CONF-2011-061)

- $t\bar{t} \to bWqZ \to b\ell\nu q\ell\ell$ topology

(2010 data, $\int Ldt = 35\ \mathrm{pb}^{-1}$)



single lepton trigger (e or μ)
2 isolated leptons, same flavour and opp. charges ($p_{\mathrm{T}} > 25, 20$ GeV)
$\geq$ 2 central jets
$\not{E}_{\mathrm{T}} > 20$ GeV
γ veto ($p_{\mathrm{T}} > 15$ GeV)
3rd lepton ($p_{\mathrm{T}} > 15$ GeV)



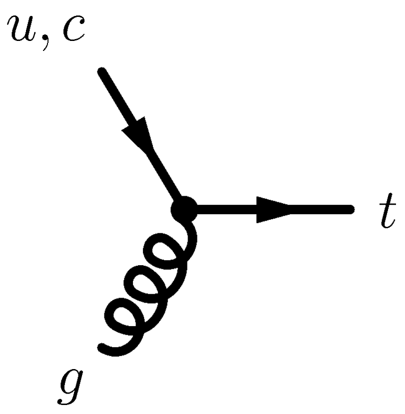
☞ No evidence for signal found

☞ 95% CL limits on $BR(t \to qZ)$:

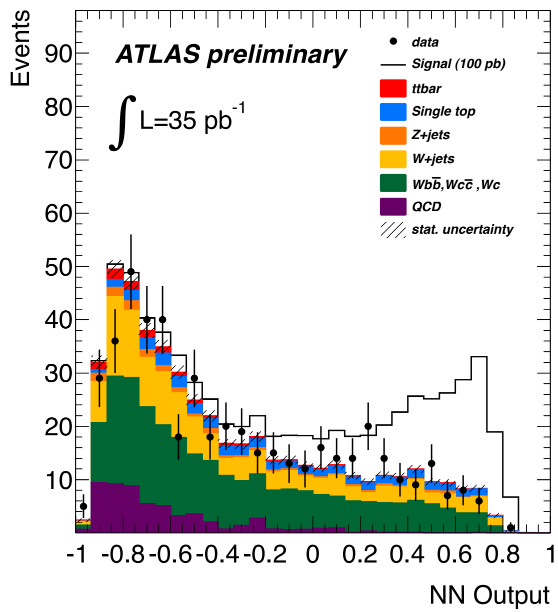
	observed	(-1σ)	expected	$(+1\sigma)$
w/o syst	16%	8%	11%	15%
w/ syst	17%	9%	12%	16%

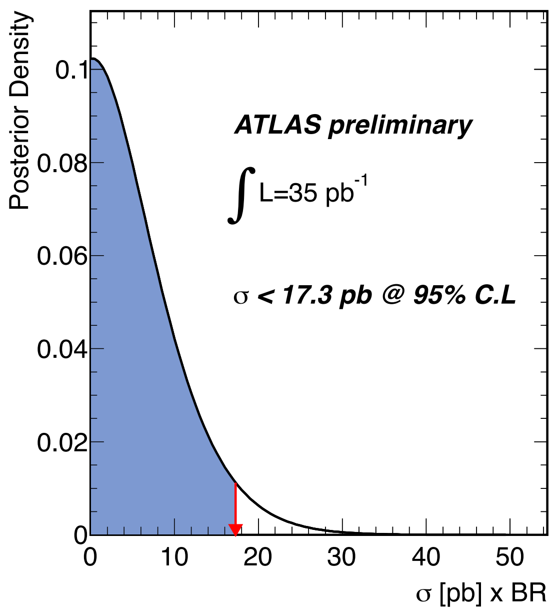
Search for FCNC (ATLAS-CONF-2011-061)

- $qg \to t \to bW \to b\ell\nu$ topology (2010 data, $\int Ldt = 35$ pb^{-1})



☞ neuronal network analysis performed





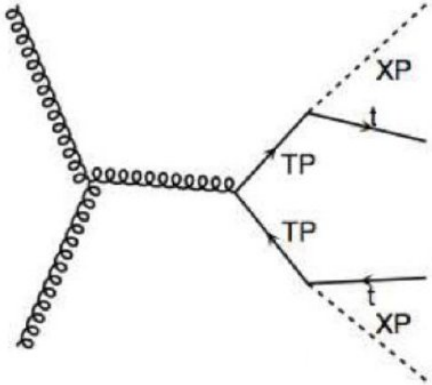
☞ No evidence for signal found

95% CL upper limits on the anomalous FCNC single top-quark production $qg \to t \to b\ell\nu$

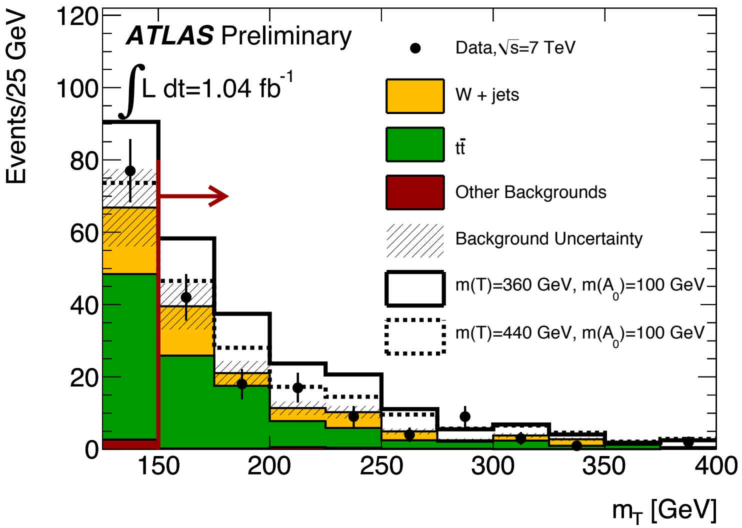
	expected			observed
	(-1σ)	median	$(+1\sigma)$	
only normalization uncertainties	9.6 pb	13.7 pb	19.7 pb	15.6 pb
with all systematics	12.0 pb	17.4 pb	25.6 pb	17.3 pb

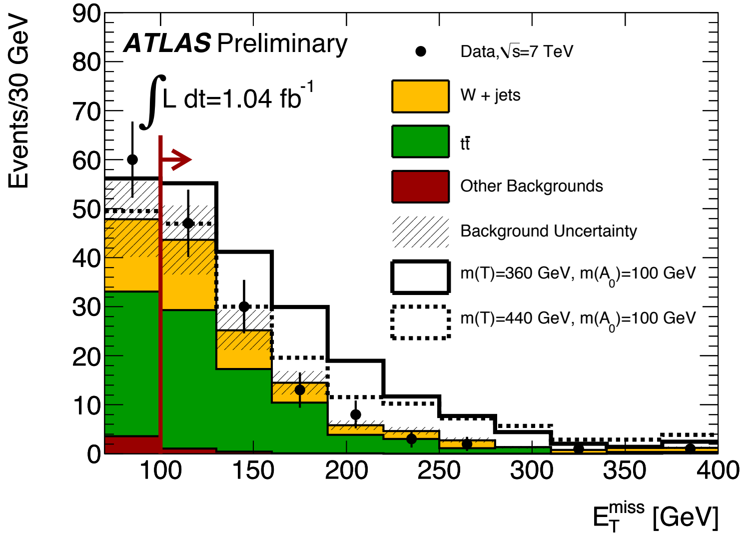
Search for $T \to tA_0$ ($t\bar{t}$ with anomalous $E_{\mathrm{T}}^{\mathrm{miss}}$)

- Search for pair production of exotic top partener (T), decaying to $t\bar{t}$ and 2 stable, neutral, weakly-interaction particles (A_0)
- In SUSY models with R-parity conservation T is the stop and A_0 the lightest SUSY particle

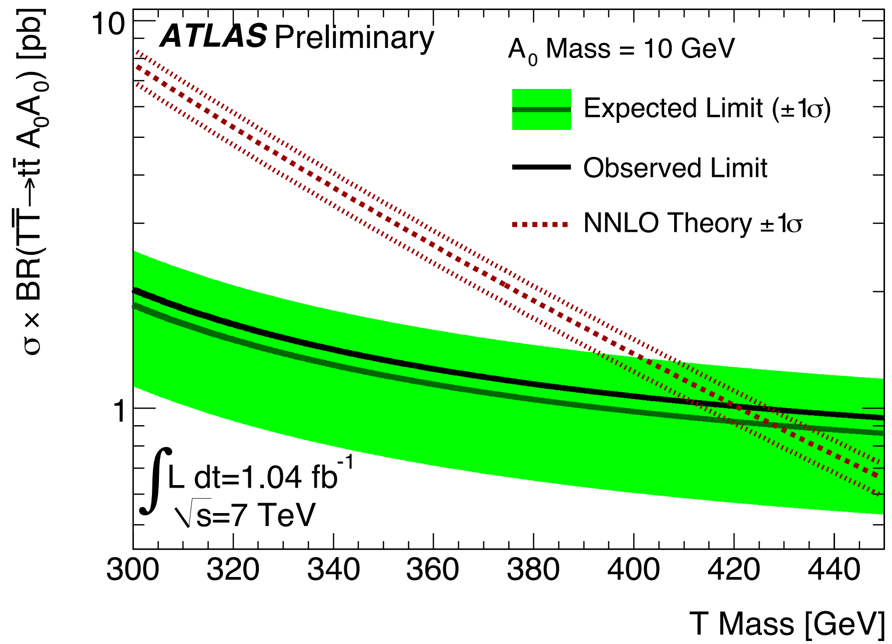


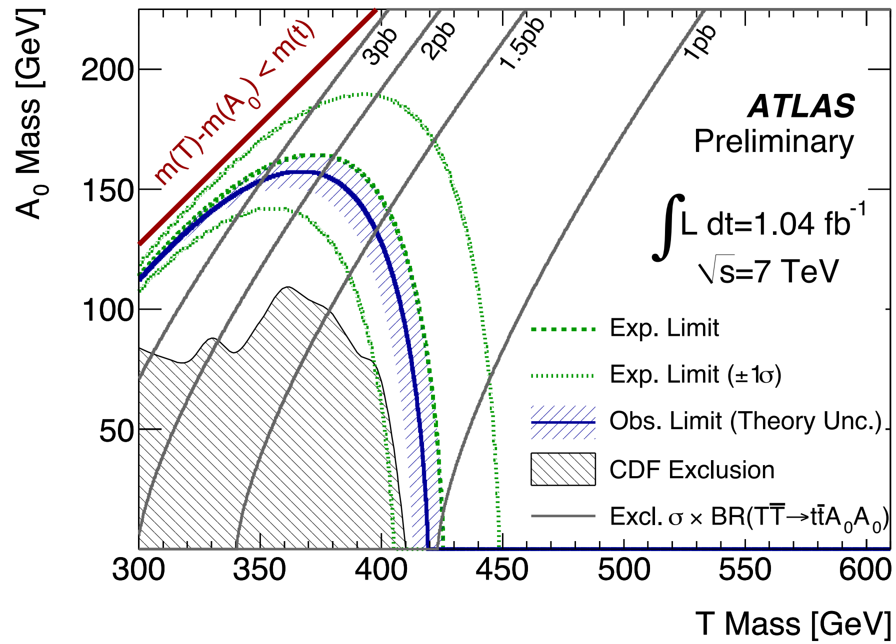
- The topology is $t\bar{t}$ with an anomalous $E_{\mathrm{T}}^{\mathrm{miss}}$ contribution
- ℓ+jets analysis w/o btagging and w/ stronger cuts on $E_{\mathrm{T}}^{\mathrm{miss}}$ and transverse mass of $\ell\nu$ (m_T)





Search for $T \to tA_0$ ($t\bar{t}$ with anomalous E_T^{miss})

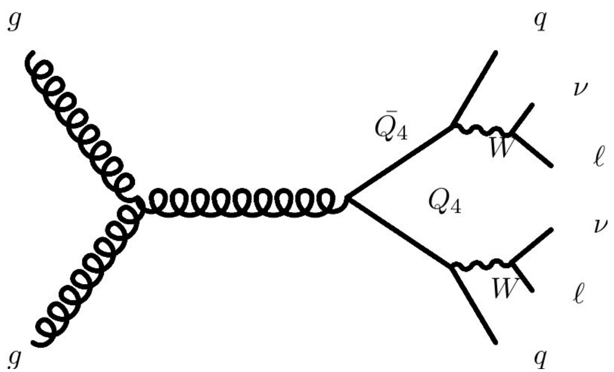


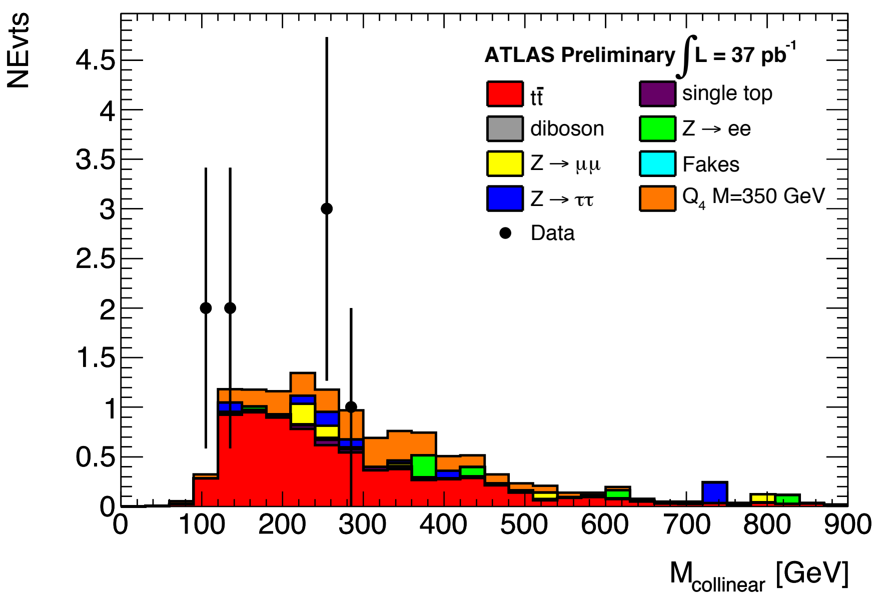


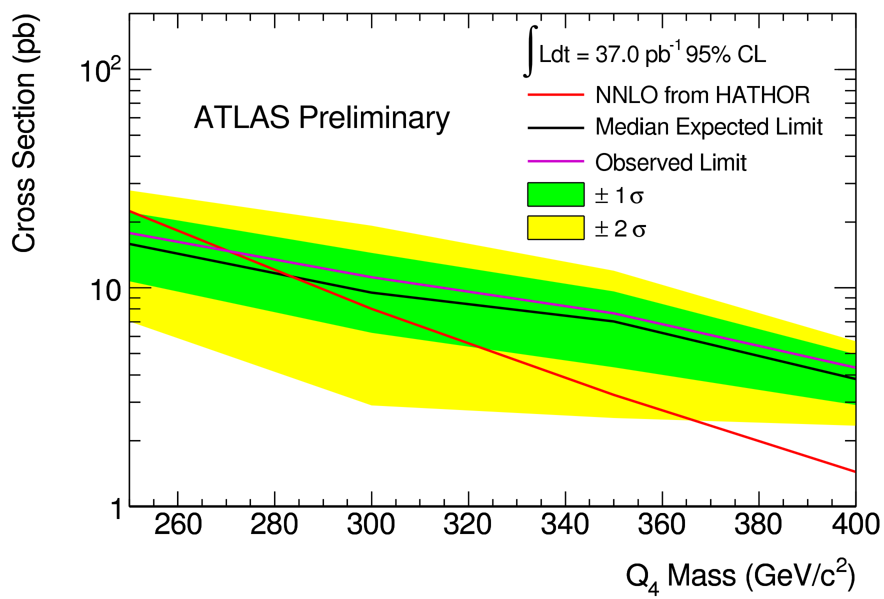
- No evidence for new physics
- 95% CL limits of $\sigma \times BR$ for different masses of T and A_0
- Assuming a model of exotic fourth generation up-type quarks [Phys.Rev.D81 (2010) 114027], these limits were converted into mass exclusion regions

Search for 4th generation quarks

- $Q_4 Q_4 \to q\bar{q}\ell^-\ell^+\nu\bar{\nu}$ ($q \neq t$) search (ATLAS-CONF-2011-022, 37 pb^{-1})
- $t\bar{t}$ dilepton as base selection
- reconstruct a “colinear” mass by scanning allowed neutrino momenta and looking for consistent Q_4 mass
- collinear mass distribution fitted to set limits

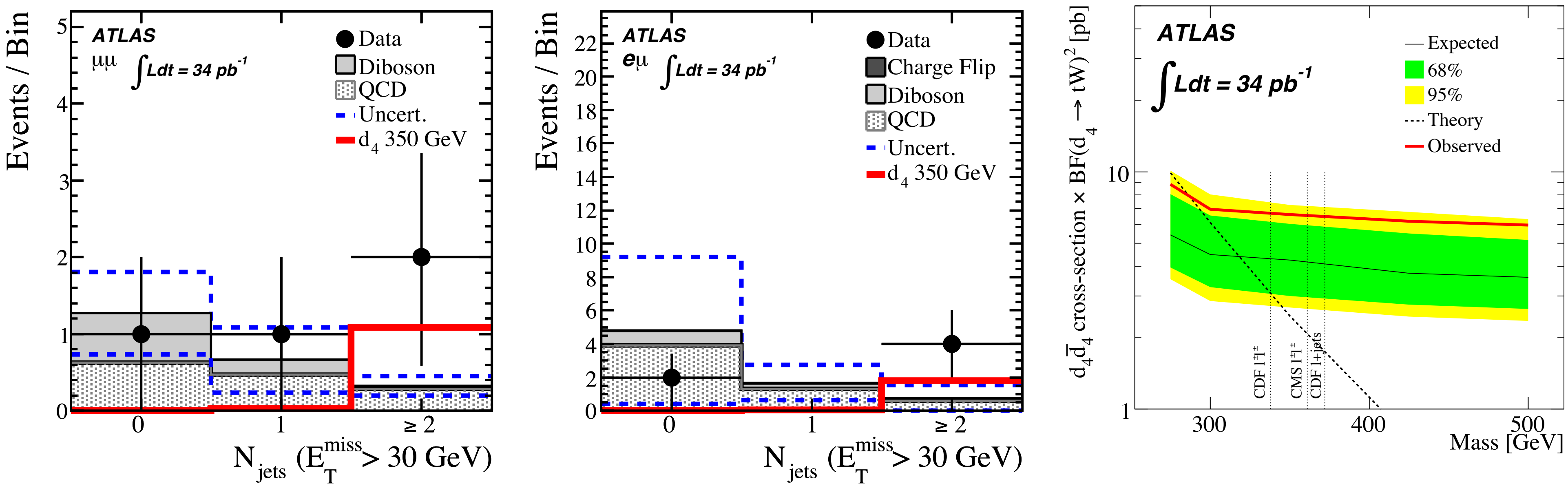






Search for $d_4 d_4$ production

- Inclusive same-sign lepton search [arXiv:1108.0366, 34 pb^{-1}]
- Sensitive to $d_4 d_4 \rightarrow ttWW \rightarrow bbjjjj\nu\nu\ell^{\pm}\ell^{\pm}$
- Set limits on $\sigma(d_4 d_4) \times BR(d_4 \rightarrow tW)^2$
  - Cut on $E_{\mathrm{T}}^{\mathrm{miss}}$
  - Fitting with jet multiplicity distribution templates



Summary

- A variety of ATLAS analysis allowing to probe new physics associated to the top and top-like quarks were presented
  - Top production
  - $t\bar{t}$ resonances
  - Charge asymmetry in $t\bar{t}$ production
  - $t\bar{t}$ spin correlations
  - W polarisation in t decays and Wtb vertex structure
  - FCNC in the top sector
  - New phenomena in $t\bar{t}$ events with large $E_{\mathrm{T}}^{\mathrm{miss}}$
  - 4th generation quarks
- The top quark looks quite SM-like (no evidence for new physics seen so far)
- This is a very active field: stay tuned for news!

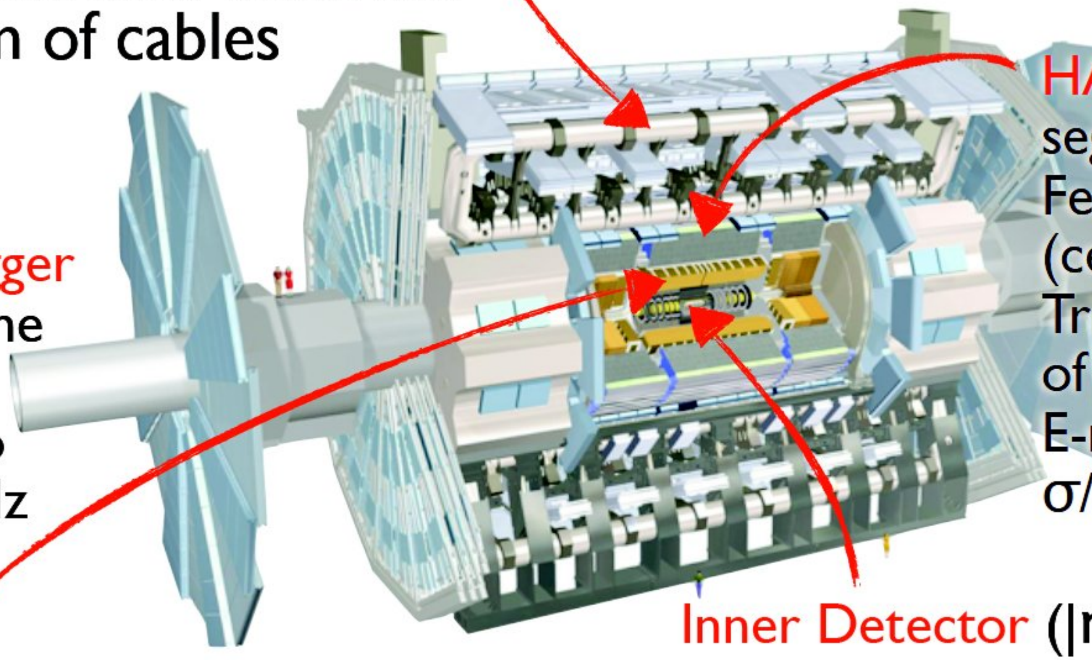
Nuno Castro is supported by FCT (project CERN/FP/116346/2010 and grant SFRH/BPD/63495/2009)

Backup Slides

The ATLAS detector

Length : ~ 46 m
Diameter : ~ 24 m
Weight : ~ 7000 tons
~10^8 electronic channels
3000 km of cables

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based muon chambers; Muon trigger and measurement with momentum resolution < 10% up to E_μ ~ 1 TeV



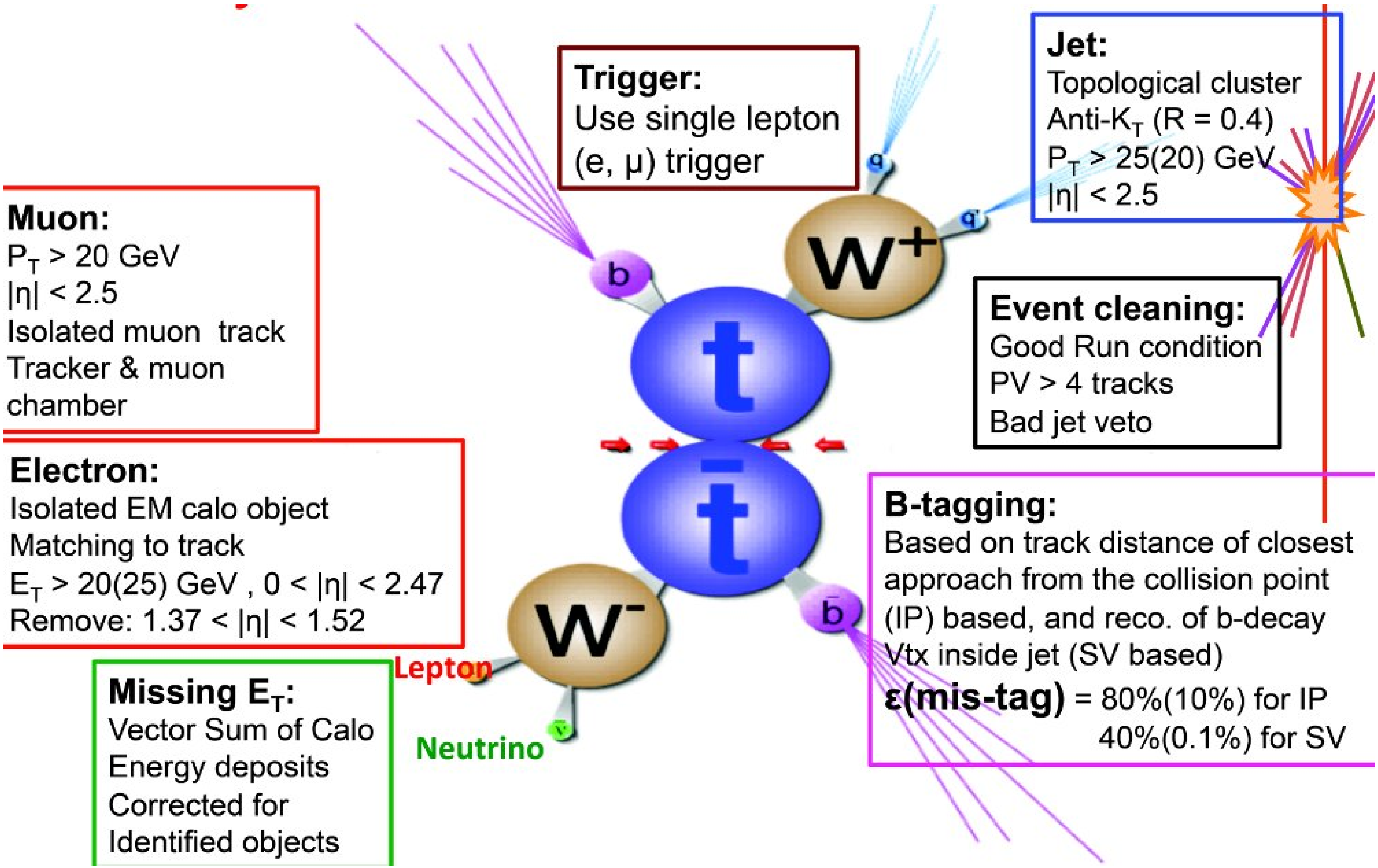
HAD calorimetry ($|\eta|<5$): segmentation, hermeticity Fe/scintillator Tiles (central), Cu/W-LAr (fwd) Trigger and measurement of jets and missing E_T
E-resolution:
$\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$

3-level trigger reducing the rate from 40 MHz to 200-300 Hz

EM calorimeter ($|\eta|<3.2$):
Pb-LAr Accordion; e/γ trigger, identification and measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

Inner Detector ($|\eta|<2.5$, B=2T): Si Pixels, Si strips, Transition Radiation detector (straws); Precise tracking and vertexing, e/π separation Momentum resolution:
$\sigma/p_T \sim 3.8\times10^{-4}\, p_T\,(\mathrm{GeV}) \oplus 0.015$
i.e. $\sigma/p_T < 2\%$ for p_T < 35 GeV

Event selection



(slide from Muhammad Saleem talk)

Event yields: $L = 0.70\ \mathrm{fb}^{-1}$ (W polarisation analysis)

ℓ+jets channel

Process	Single electron channel	Single muon channel
$t\bar{t}$	2200 ± 400	3200 ± 500
Single top	120 ± 10	160 ± 10
Misidentified leptons	80 ± 80	200 ± 200
W+jets	300 ± 160	500 ± 250
Z+jets	30 ± 20	40 ± 20
Diboson	5 ± 1	8 ± 1
Total predicted	2800 ± 400	4100 ± 600
Data	3006	4313

dilepton channel

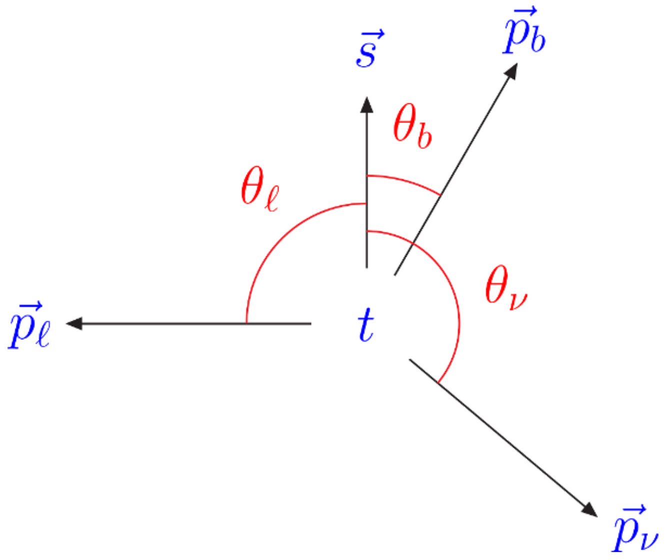
Process	ee channel	$\mu\mu$ channel	$e\mu$ channel
$t\bar{t}$	80 ± 20	160 ± 20	540 ± 50
Single top	3 ± 1	7 ± 1	22 ± 3
Misidentified leptons	2 ± 1	0 ± 1	30 ± 20
Z ($\rightarrow ee/\mu\mu$) +jets	3 ± 3	4 ± 2	—
Z ($\rightarrow \tau\tau$) + jets	2 ± 1	5 ± 1	26 ± 5
Diboson	2 ± 1	4 ± 9	14 ± 2
Total predicted	90 ± 20	180 ± 20	630 ± 60
Data	103	175	643

Probing the *Wtb* vertex: spin asymmetries

- polarised top decays

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_X} = \frac{1+\alpha_X\cos\theta_X}{2}$$

☞ α_X depends on the anomalous couplings



X = top decay product ➞ $\vec{p}_X$ = momentum in t rest frame

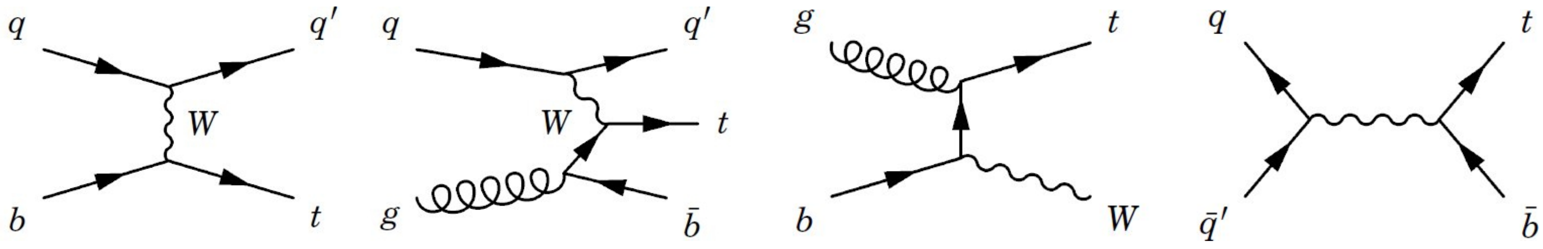
$\vec{p}_j$ = jet momentum in t rest frame

$Q = \cos(\vec{p}_X, \vec{p}_j)$ ➞

$$A_X \equiv \frac{N(Q>0)-N(Q<0)}{N(Q>0)+N(Q<0)} = \frac{1}{2}P\alpha_X \quad [P=0.95\ (t) \quad P=-0.93\ (\bar{t})]$$

[PLB 476 (2000) 323]

Probing the *Wtb* vertex: single top production cross-section

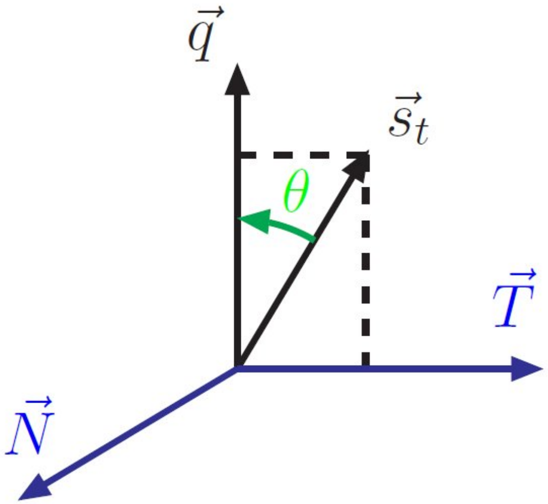


$$\sigma = \sigma_{SM}\left(V_L^2 + \kappa^{V_R}\, V_R^2 + \kappa^{V_L V_R}\, V_L V_R + \kappa^{g_L}\, g_L^2 + \kappa^{g_R}\, g_R^2 + \kappa^{g_L g_R}\, g_L g_R + \ldots\right)$$

- the κ factors determine the dependence on anomalous couplings
- the κ factors are, in general, different for t and $\bar{t}$ production
- the measurement of the single top production cross-section allows to obtain a measurement of V_L ($\equiv V_{tb}$) and bounds on anomalous couplings

W polarisation beyond helicity fractions

- New idea to study top decays: [NPB840 (2010) 349]
  ☞ consider transverse and normal directions



$\vec{q}$ → W mom in t rest frame
$\vec{s}_t$ → top spin

$$\vec{N} = \vec{s}_t \times \vec{q}$$
$$\vec{T} = \vec{q} \times \vec{N}$$

meaningful for polarised t decays
(e.g. in single top production)

θ_ℓ^* → angle between ℓ, $\vec{q}$
determine F_+, F_0, F_-

θ_ℓ^T → angle between ℓ, $\vec{T}$
determine F_+^T, F_0^T, F_-^T

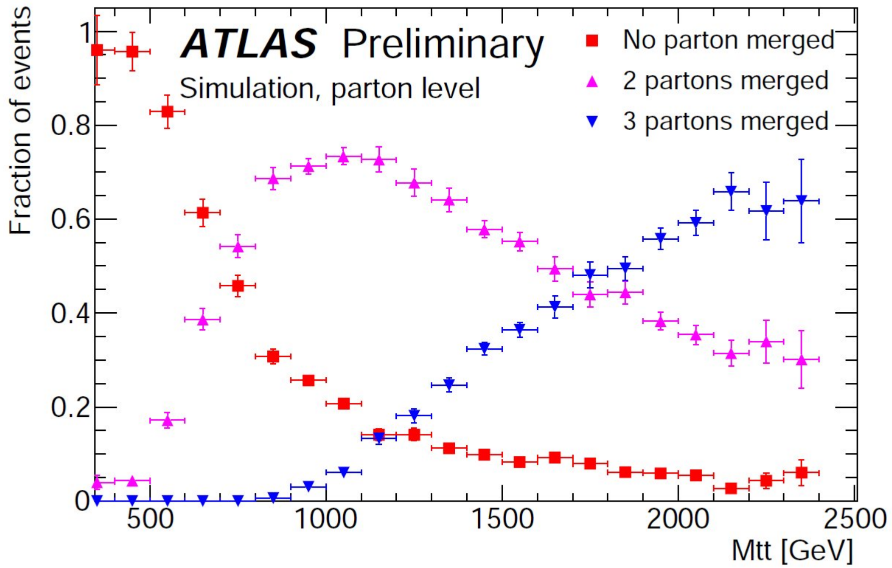
θ_ℓ^N → angle between ℓ, $\vec{N}$
determine F_+^N, F_0^N, F_-^N

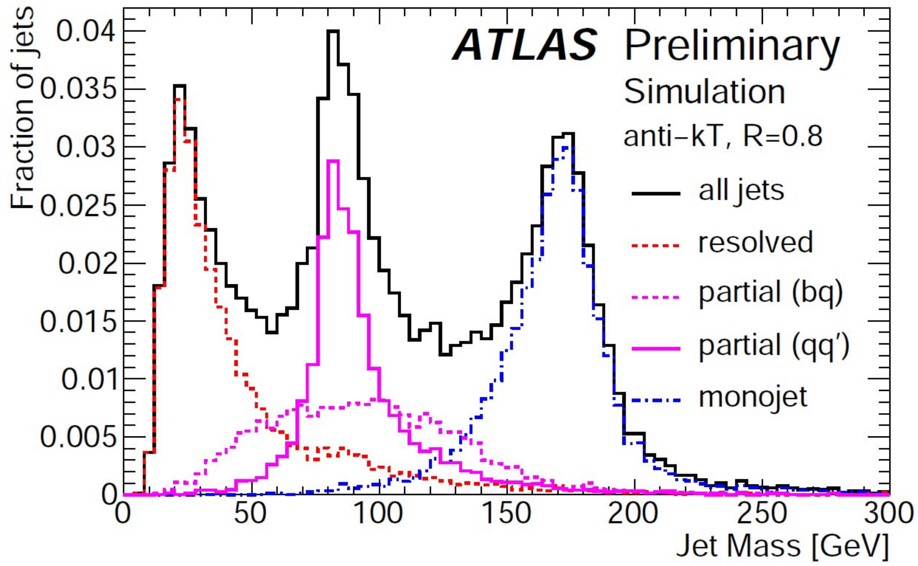
$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_\ell^X} = \frac{3}{8}(1+\cos\theta_\ell^X)^2\, F_+^X + \frac{3}{8}(1-\cos\theta_\ell^X)^2\, F_-^X + \frac{3}{4}\sin^2\theta_\ell^X\, F_0^X$$

$$A_{\mathrm{FB}}^N = \frac{3}{4}\left[F_+^N - F_-^N\right]$$

$$\boxed{A_{\mathrm{FB}}^N \simeq 0.64\, P\, \mathrm{Im}\, g_R}$$

$t\bar{t}$ resonances: boosted objects

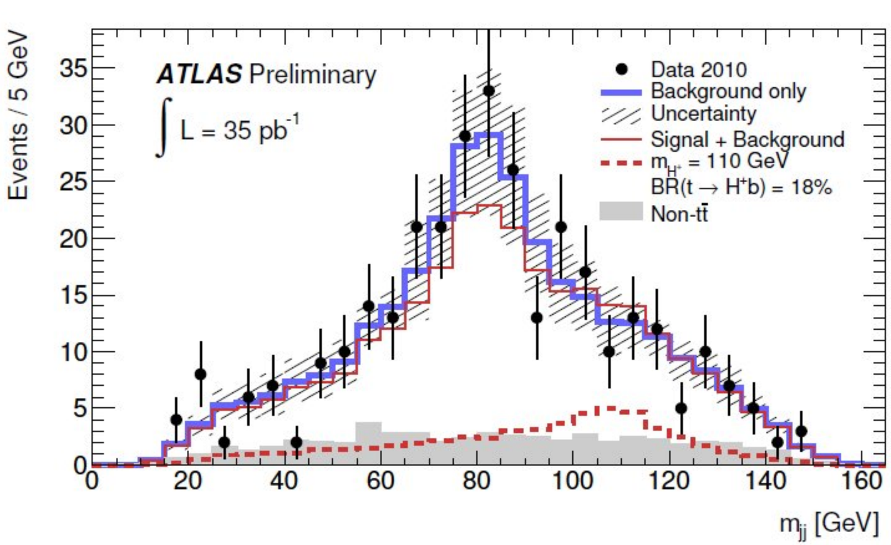


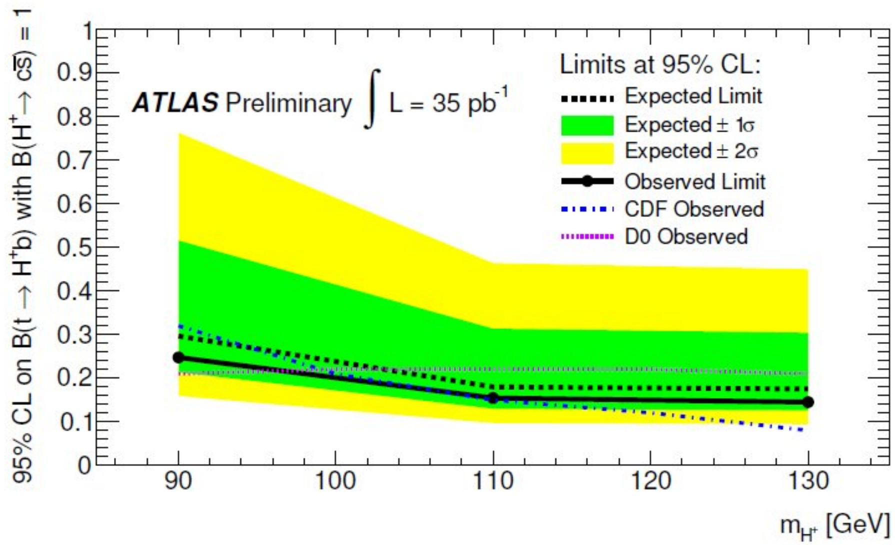


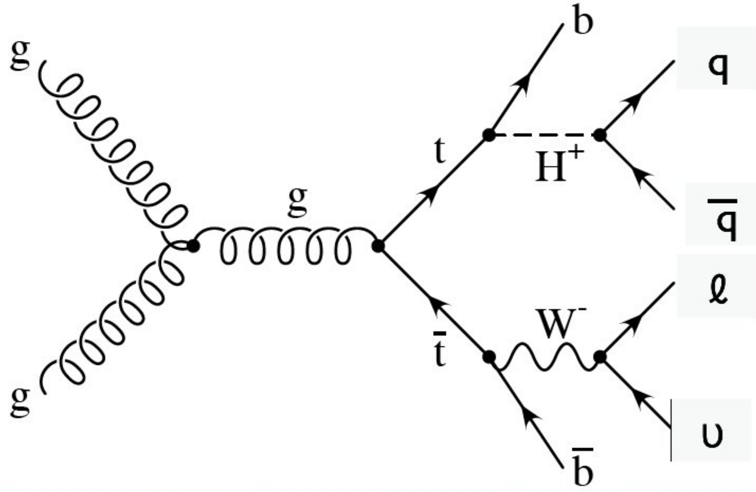
Search for $H^+ \to c\bar{s}$

Search for charged Higgs $H+ \to c\bar{s}$ in top decays

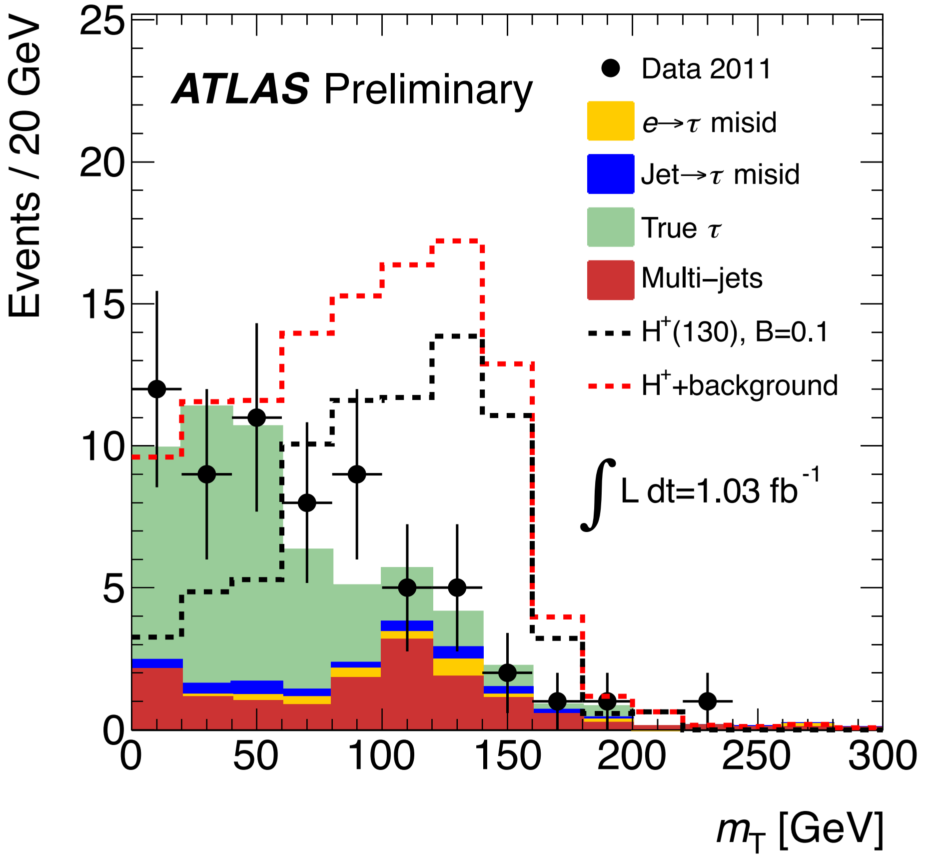
ATLAS-CONF-2011-094

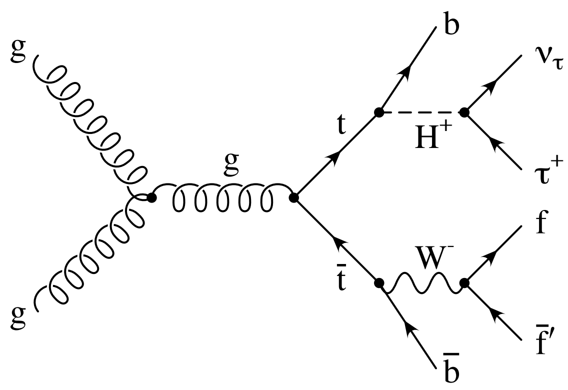


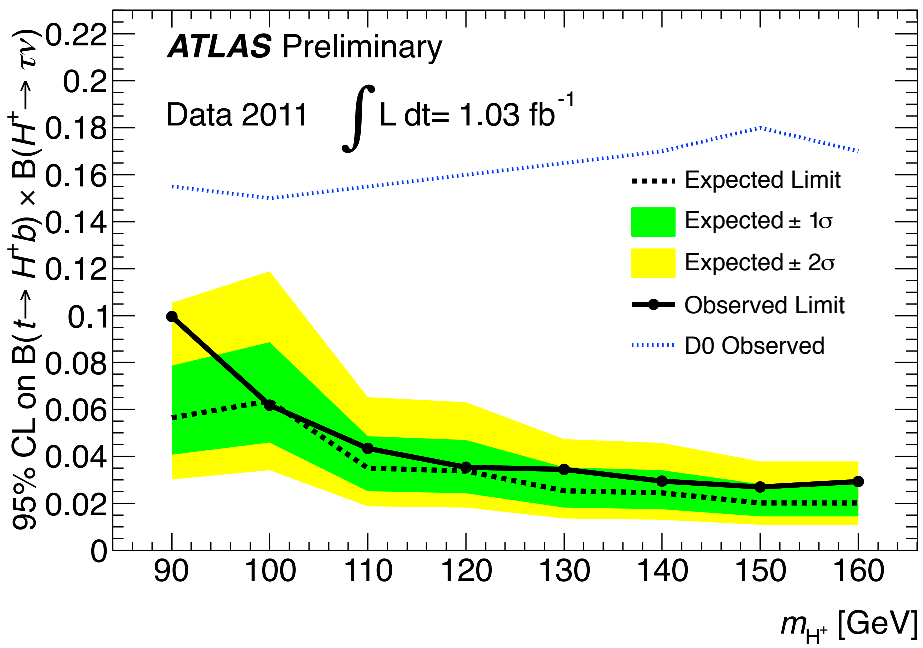




Search for $H^+ \to \tau\nu$ (ATLAS-CONF-2011-138)







- Both the W and the τ decay hadronically