Search for Exotics Physics States in Jets and Boosted Objects Final states

Ludovica Aperio Bella (LAPP , CNRS/IN2P3, Annecy-le-Vieux, France)
on behalf of the ATLAS Collaboration

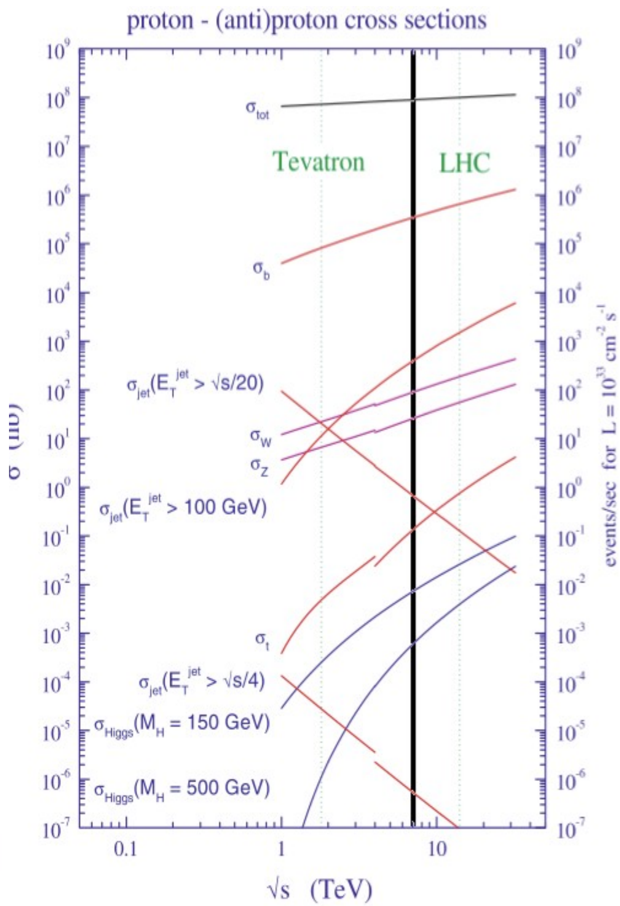
PLHC 2012 Vancouver

Outline

- Searches for new phenomena with *jets in the final state*:
  - Searches for resonances e.g. exited quark search
    - *Dijet invariant mass distribution*
    - *γ-jet invariant mass distribution*
  - Searches for resonant and no-resonant processes e.g. extra-dimension
    - *Dijet angular distribution*
    - *MonoJet + missing transverse energy final state*
- Search of new High-Scale physics scenarios which often produce Ws or tops at high energy (*boosted object*):
  - *Search for $t\bar{t}$ resonances in the l+jets channel*
  - *Search of exotic heavy quarks (b'b' →WtWt→$l^{\pm}\nu$+jets)*

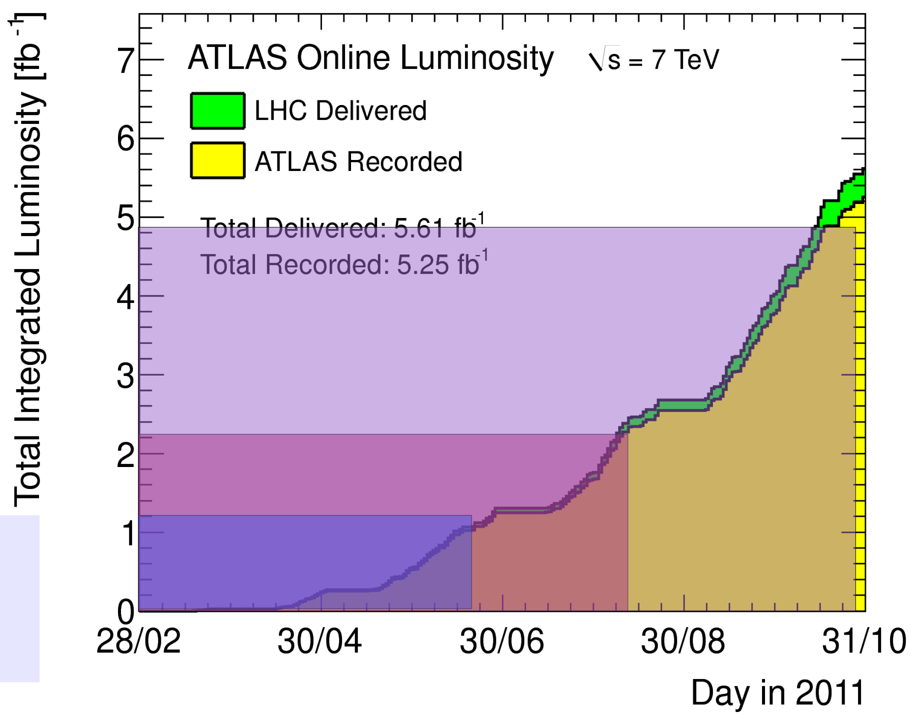
Motivation

The LHC offers the opportunity to search for physics beyond the Standard Model (SM) by opening a new energy frontier

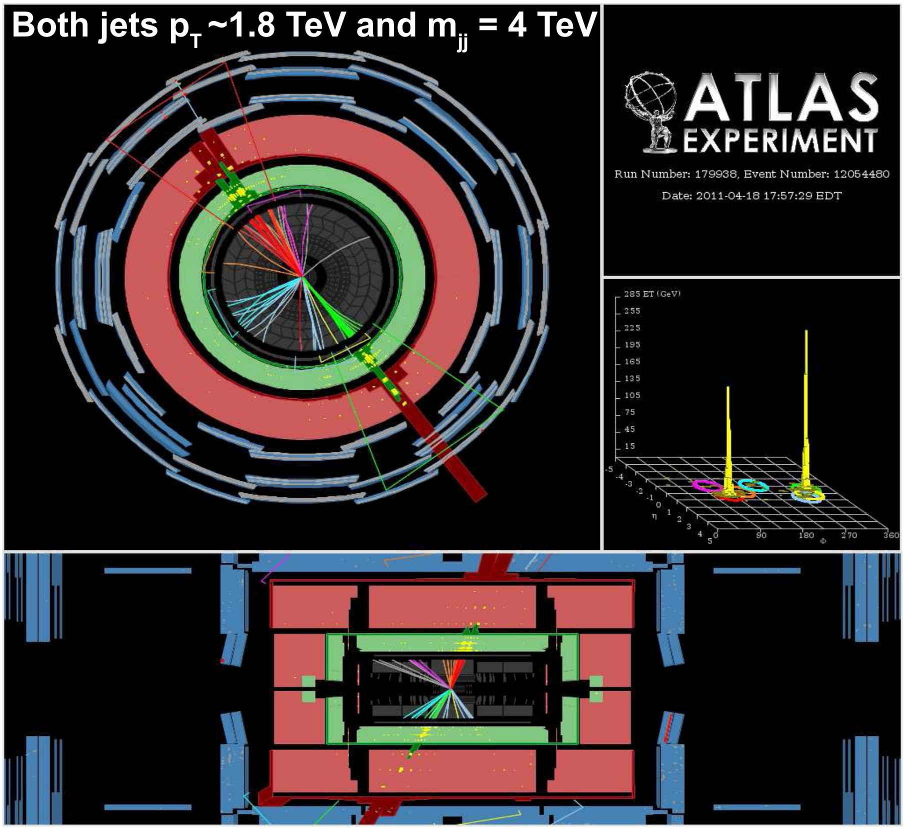


- Searches at ATLAS for new physics involving final states with **one or more jets** as the most prominent signatures
  → Cross sections for colored processes typically much larger than for uncolored processes
  → Highest energies directly accessible by LHC

ATLAS results shown in this talk based on 7 TeV collisions recorded in 2011:
- More than 5 fb^{-1} collected



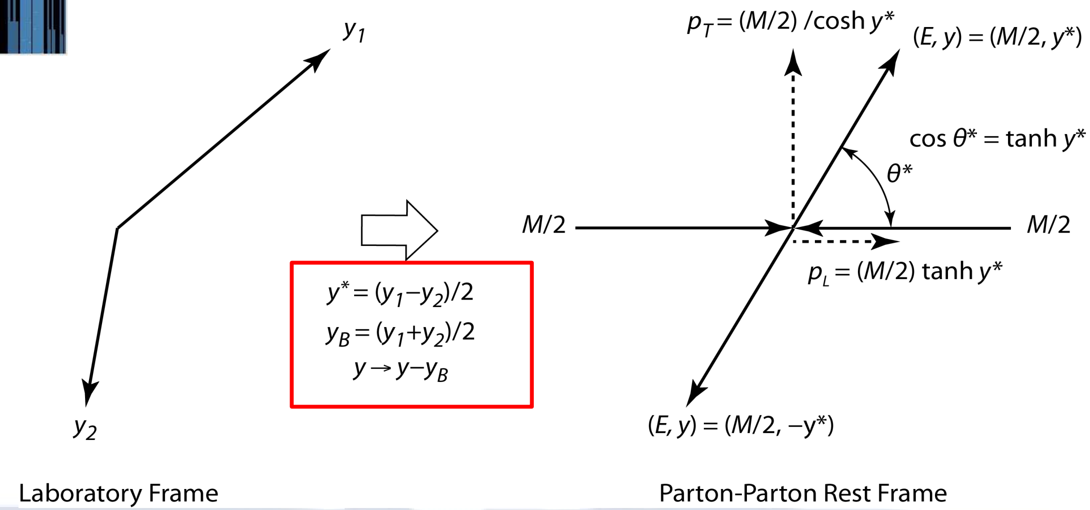
Dijet analysis



Many models predict resonances with two-body decays to jets:

- Z'
- Excited quarks,
- Color octets,
- Axigluons,
- Black holes,
- KK gravitons

New physics tends to prefer <u>central production</u> (s-channel)
QCD multijets has strong t-channel component (mostly forward)



Dijet Mass distribution

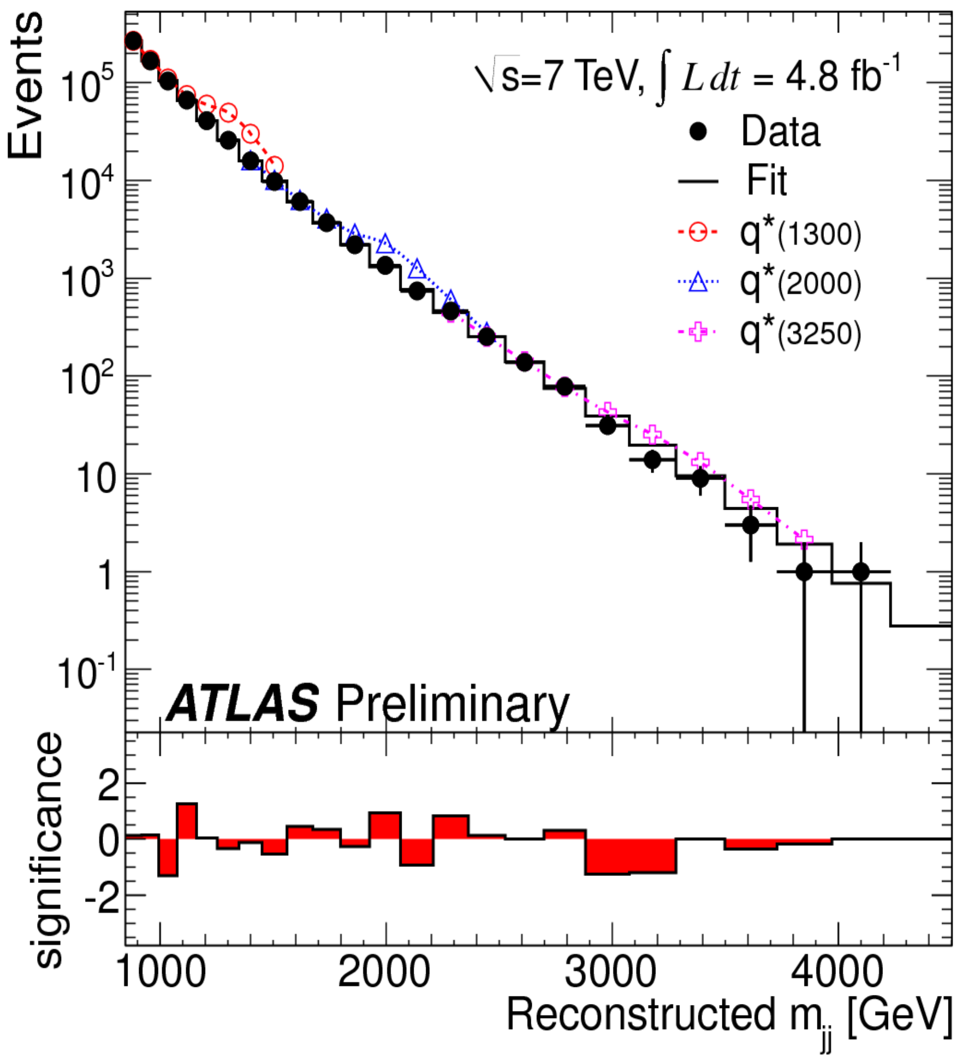
Bump search in dijet mass distribution:

- At least 2 jets p_T^1>100GeV p_T^2>50GeV)
- m_{jj}>850 GeV
- Shape comparison in | y*| < 0.6

Background estimate:
Fit mass distribution to background hypothesis massless 2 → 2 scattering Formulae:

$$f(x) = p_0 \frac{(1-x)^{p_1}}{x^{p_2+p_3 \ln x}}, \quad x \equiv \frac{m_{jj}}{\sqrt{s}}$$

Perform **BumpHunter search**
→ most significant deviation from background has pvalue: 96% in m_{jj} range has [1.08 – 1.25] TeV



No Evidence for a resonance signal in the m_{jj} spectrum

Dijet angular distribution

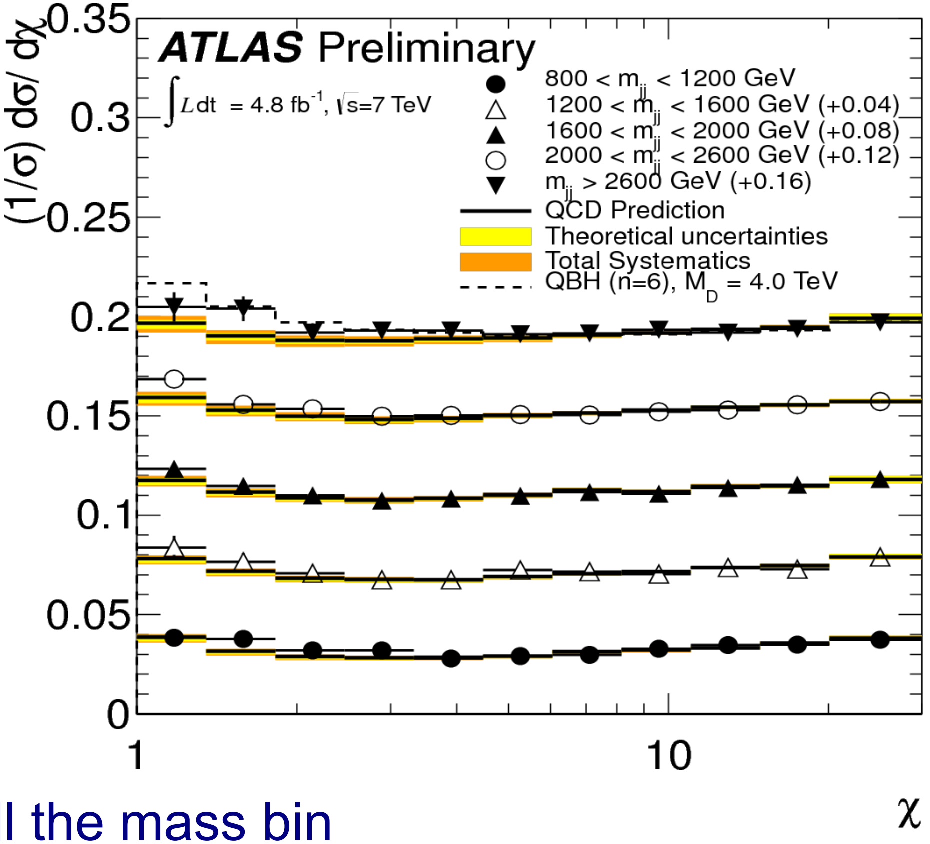
Some new physics will not produce a peak in the dijet mass distribution but could appear in angular distribution e.g., effective contact interaction.

- At least 2 jets $p_T^1>100$GeV $p_T^2>50$GeV)
- $m_{jj}>850$ GeV

$$\chi \equiv \exp(|y_1 - y_2|)$$

$$y^* = \pm\frac{1}{2}(y_1 - y_2)$$

$$|y^*|<1.7 \rightarrow \chi<30$$



Background estimate:

2 → 2 Pythia with NLOJet++ k-factor in each χ and m_{jj} bin

Two statistical tests:

- p-value with binned likelihood for all the mass bin
- BumpHunter algorithm applied to all the χ distribution

Data in agreement with the QCD prediction

Dijet angular distribution

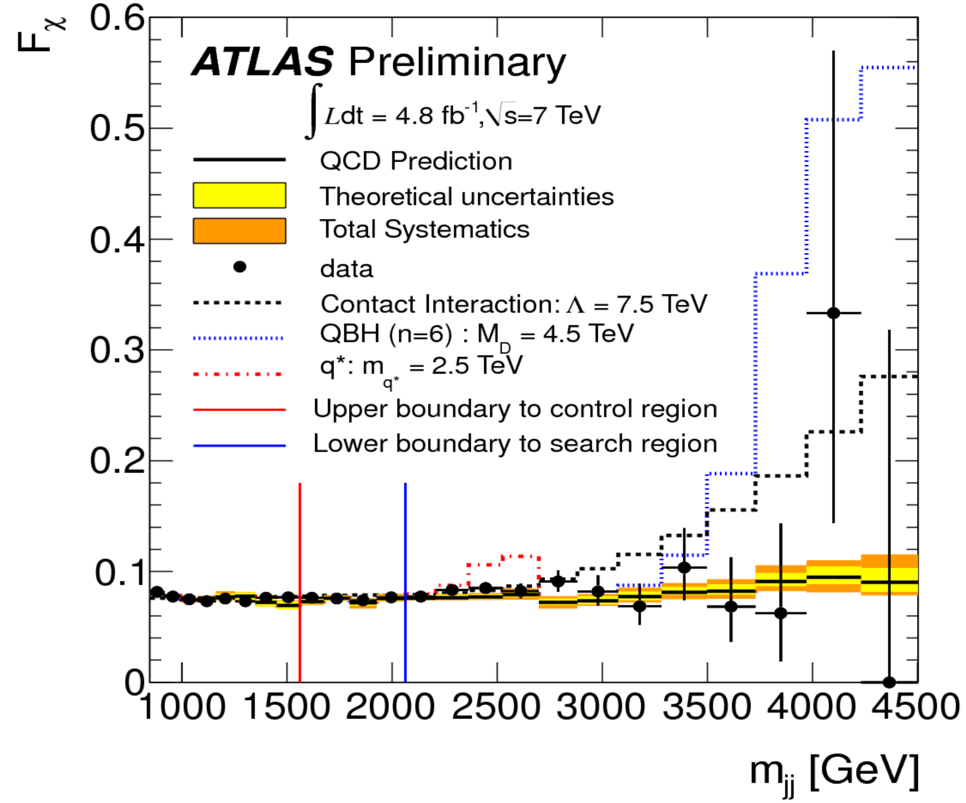
Single parameter to measure the isotropy of jet production $F_\chi(m_{jj})$. This distribution is more sensitive to mass-dependent change in the rate of centrally produced dijets.

$$F_\chi = \frac{N_{\mathrm{central}}}{N_{\mathrm{total}}}$$

$N_{central}$: events with $|y^*|<0.6 \rightarrow \chi<3.32$

N_{total}: events with $|y^*|<1.7 \rightarrow \chi<30$

$$y^* = \pm\frac{1}{2}(y_1 - y_2)$$



Background estimate:

2 → 2 Pythia with NLOJet++ k-factor in each χ and m_{jj} bin

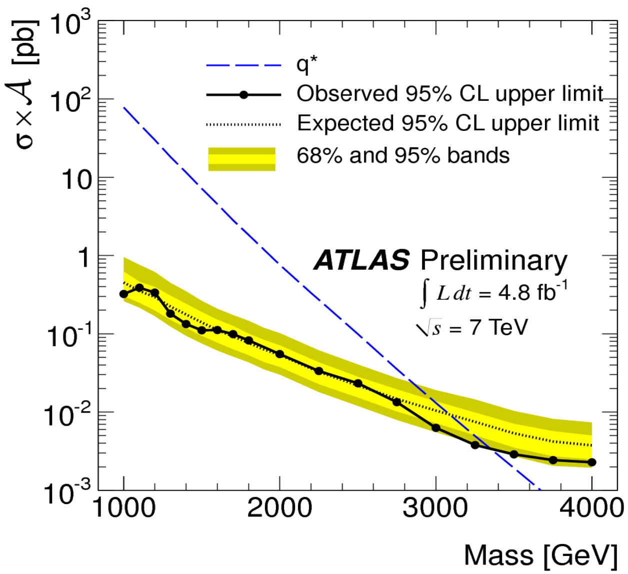
Two statistical tests:

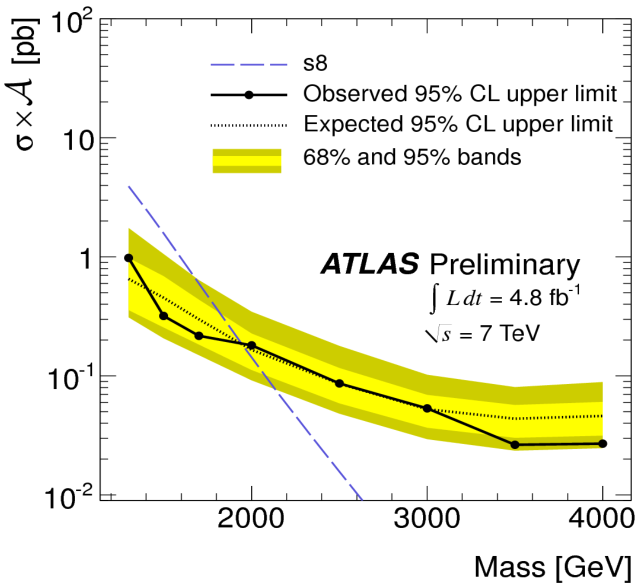
- p-value with binned likelihood for high mass region of 0.052
- BumpHunter and TailHunter → most discrepant range [2.2-3.5] TeV: 1.39σ

Data in agreement with the QCD prediction

Dijet analysis Limits results

Bayesian 95% C.L. upper limits on σ x A for the m_{jj} distribution

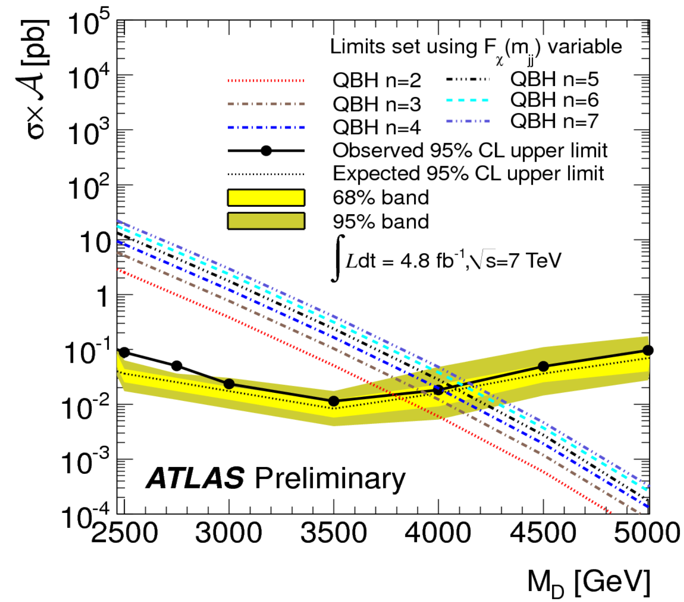




Excited quark mass:
q* < 3.35 TeV (3.09) TeV

Color octet scalar mass:
s8<1.94 TeV(1.94)TeV

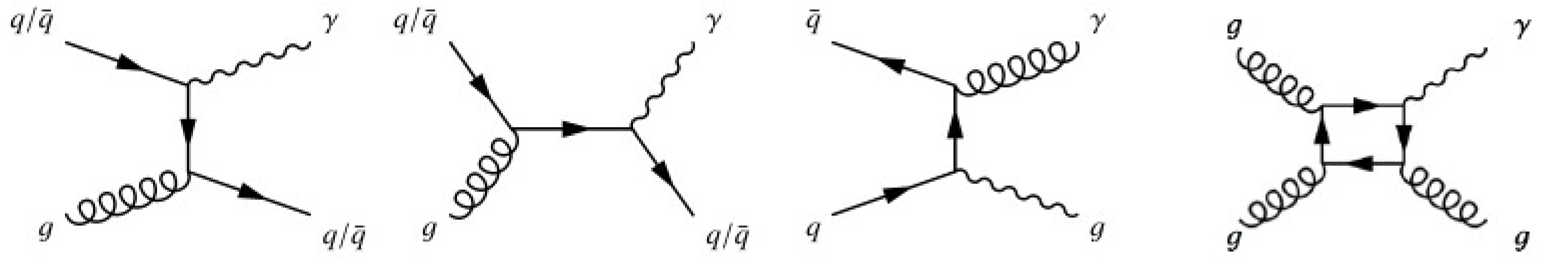
Bayesian 95% C.L. upper limits on σ x A for the $F_\chi(m_{jj})$ distribution



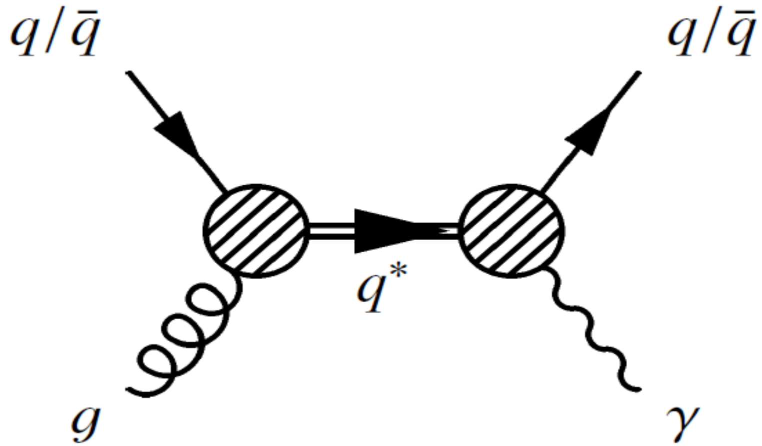
Quantum Black Hole:
QBH < 4.11 TeV (4.14) TeV

γ-jet analysis

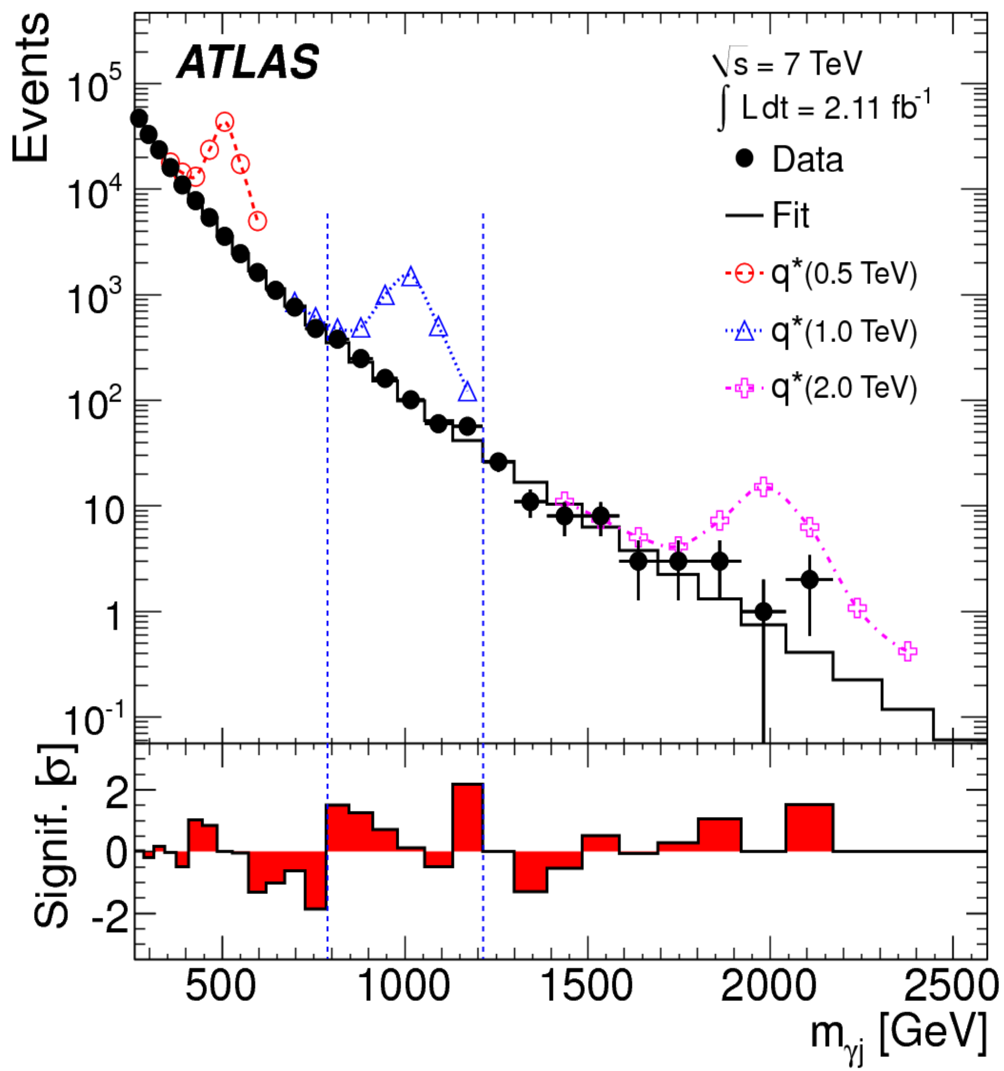
Photon+jet final state sensitive to many models: excited quarks, Regge recurrences, topological pions.
Backgrounds: SM Photon+Jet and dijets with fragmentation photon



Complementary to dijet searches for some models (e.g. excited quarks) → Excited quark model used as benchmark model



γ-jet invariant mass distribution



Selection:

- At least one isolated γ with p_T>85 GeV
- At least one jet with p_T>30 GeV
- ΔR > 0.4 between γ and any jet
- $m_{\gamma j}$ > 260 GeV

Background estimate:

Fit mass distribution background hypothesis massless 2->2 scattering formula:

$$f(x) = p_0 \frac{(1-x)^{p_1}}{x^{p_2+p_3 \ln x}}, \quad x \equiv \frac{m_{jj}}{\sqrt{s}}$$

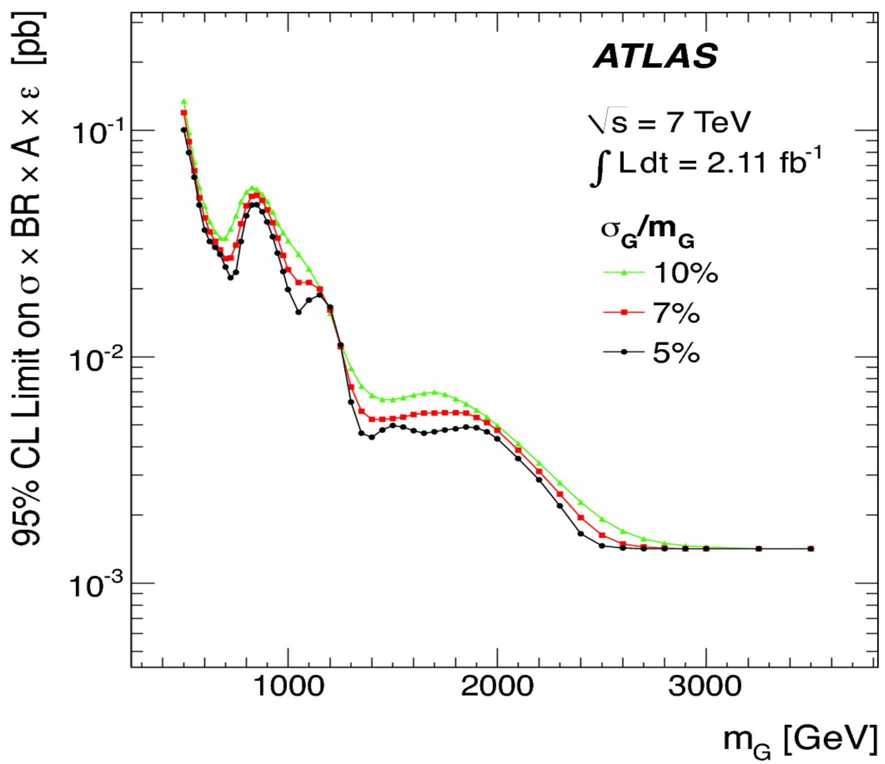
Bump Hunter:

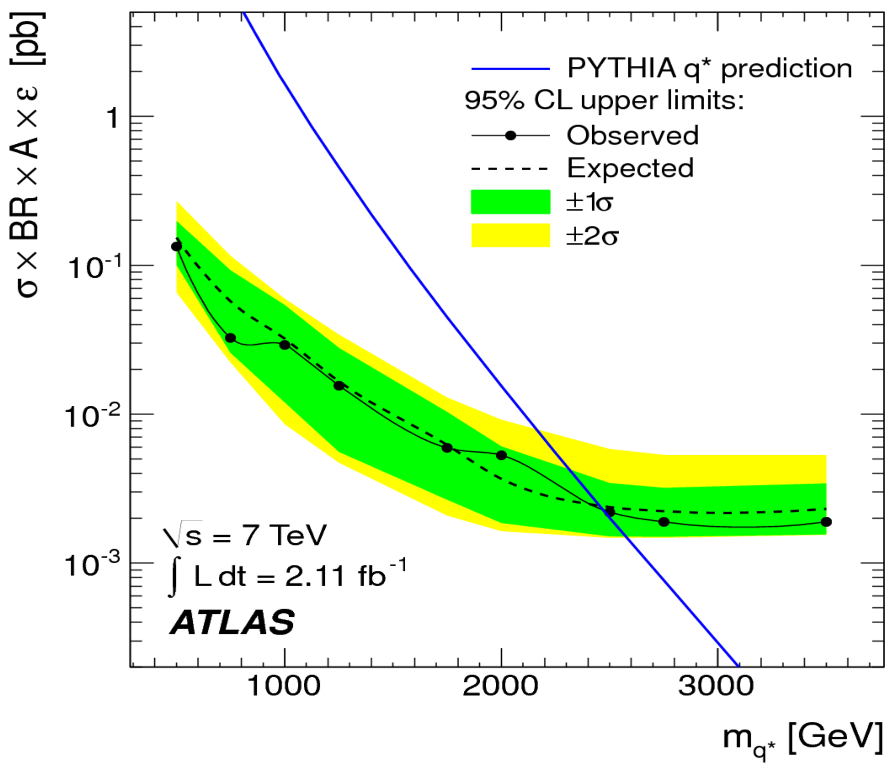
Most significant excess appears in the interval [784-1212] GeV p-value of 0.20

No Evidence for a resonance in the $m_{\gamma j}$ spectrum

γ-jet Limits

Set 95% CL Bayesian limit:



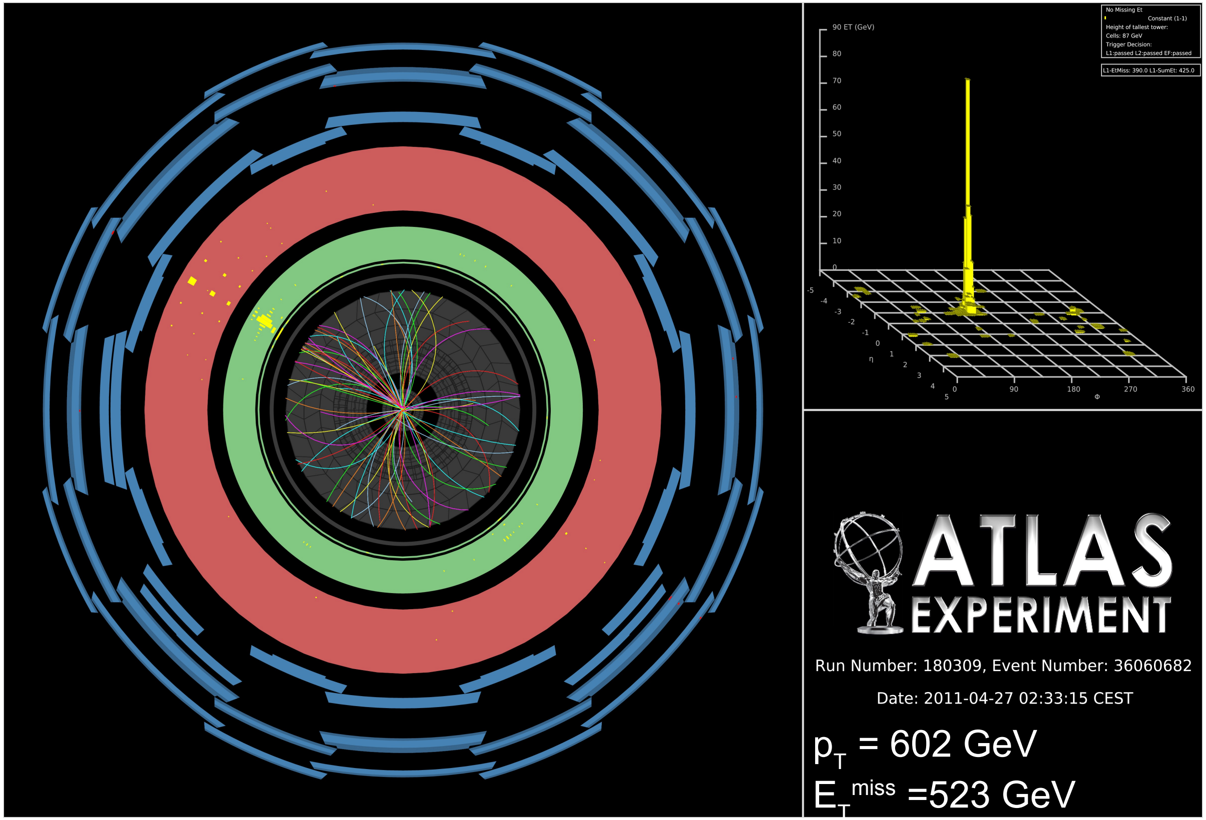


Generic Gaussian-shape resonances for three values of the relative Gaussian width σ_G / m_G

Excited quark model:
Exclude **m(q*) < 2.46 TeV**

Complementary but best limit from dijet exclusion ~3TeV

MonoJet analysis



Many possible signals: graviton emission, unparticles, wimps, (SUSY)

Selection:

- Large missing E_T
- Exactly one high p_T jet
- No second jet
- No electrons or muons
- $\Delta\varphi$(jet: E_T^{miss}) > 0.5

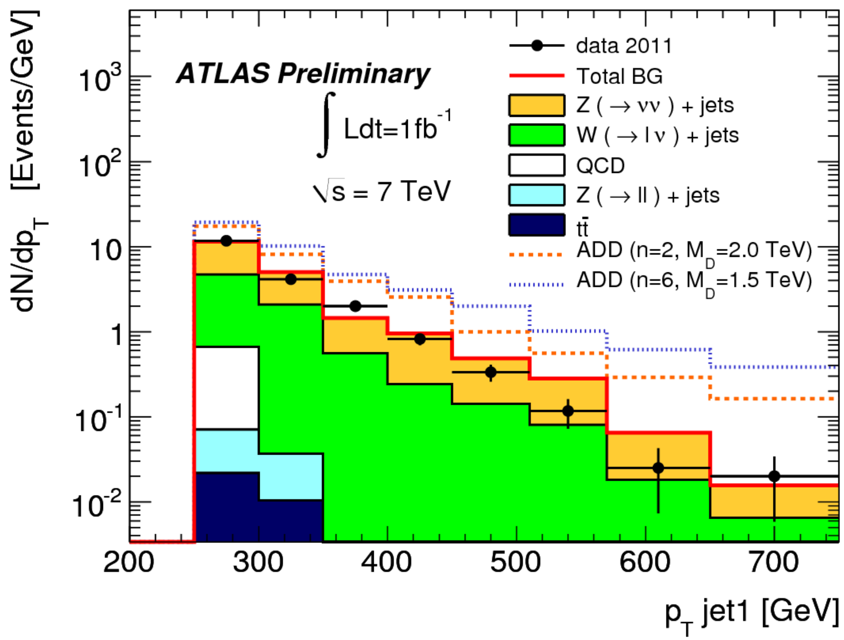
Background evaluation:

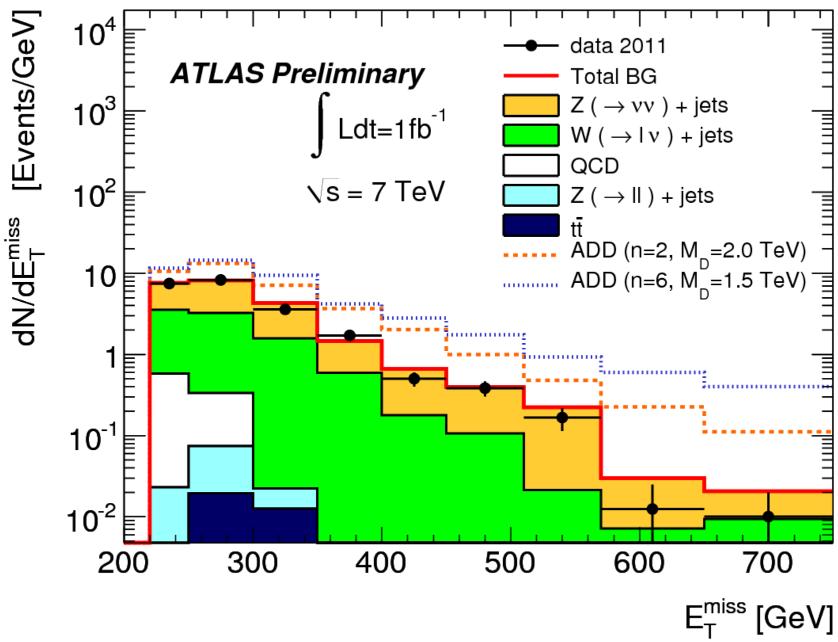
Z/W+jets: dominant contribution
MC estimate + rescaling from data.
Z → **νν** (irreducible) and **tt**bar→MC
Multi-jets bkg contribution→data-driven
Non collision bkg → data

	Low p_T	High p_T	Very high p_T
Jet p_T >	120 GeV	250 GeV	350 GeV
E_t^{miss} >	120 GeV	220 GeV	300 GeV
Second Jet p_T <	30 GeV	60 GeV	60 GeV

Jet + missing E_T Results

- High-p_T signal region



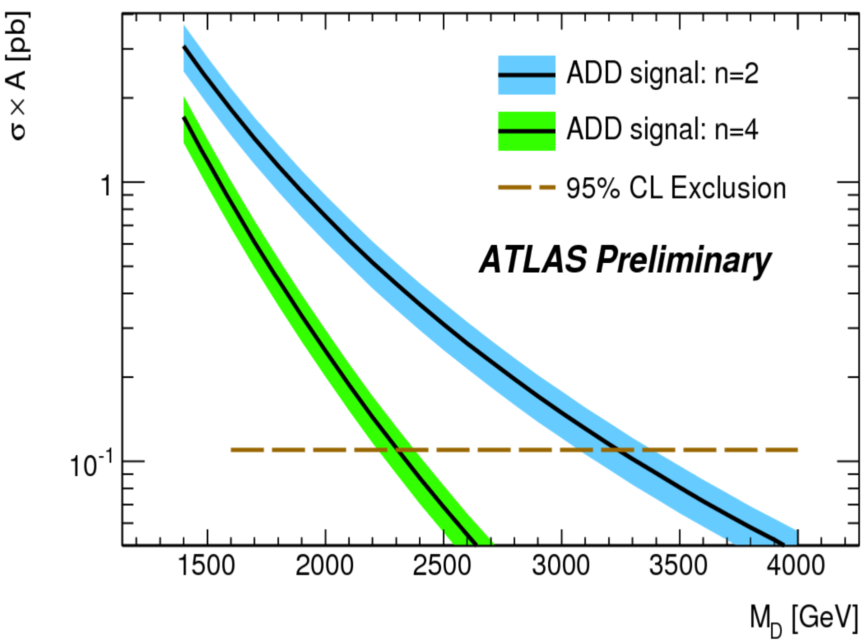


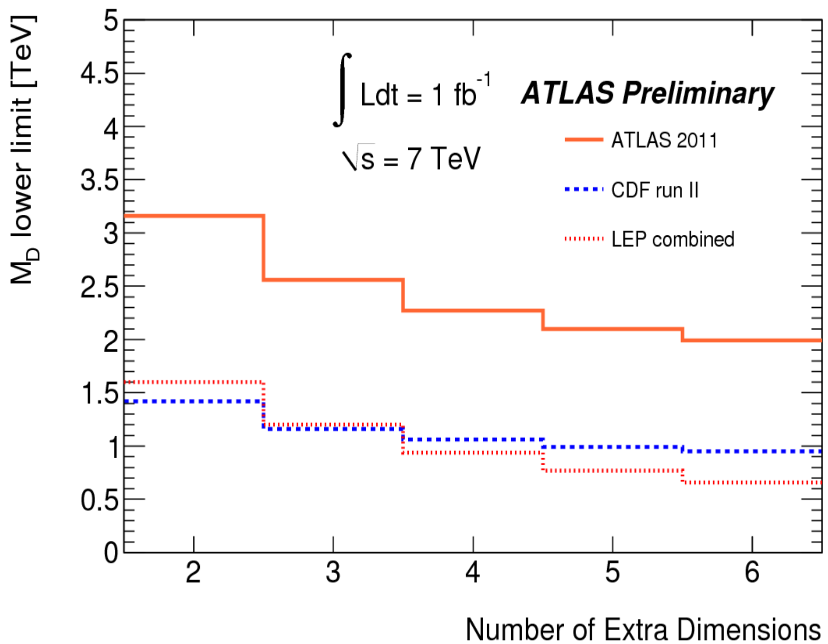
Good agreement data and MC prediction

	Low p_T	High p_T	Very high p_T
Jet p_T >	120 GeV	250 GeV	350 GeV
E_t^{miss} >	120 GeV	220 GeV	300 GeV
Second Jet p_T <	30 GeV	60 GeV	60 GeV

Jet + missing E_T exclusion Limit

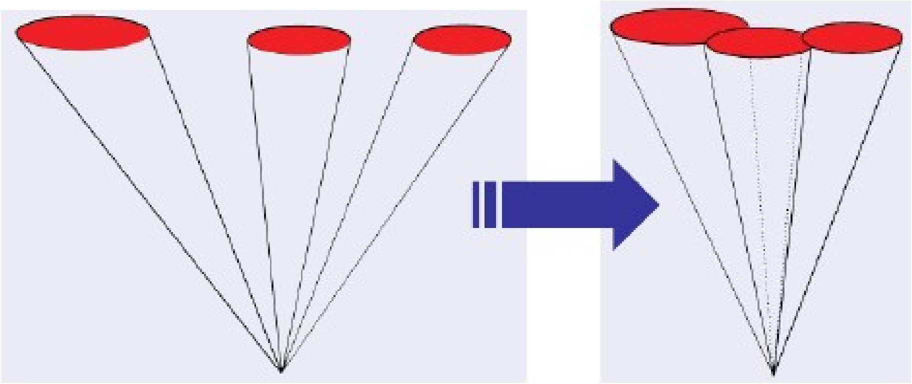
- No excess observed → set model-independent 95% CL limits on the effective cross section (product of cross section and acceptance) of the signal:
  - **Low-p_T: 1.7 pb**
  - **High-p_T: 110 fb**
  - **Very High-p_T: 35 fb**
- High-p_T limits in the context of ADD models:





Why Boosted?

- Something heavy (e.g. Z') decays to something lighter (t,W/Z,H,. . .), which is then naturally boosted
  - For very massive resonances W boson and even top decays products can be reconstructed as a “fat jet” → *Boosted topology*



- The searches presented in this talk:
  - Search for $t\bar{t}$ resonances in the l+jets channel **2.05 fb^{-1}**

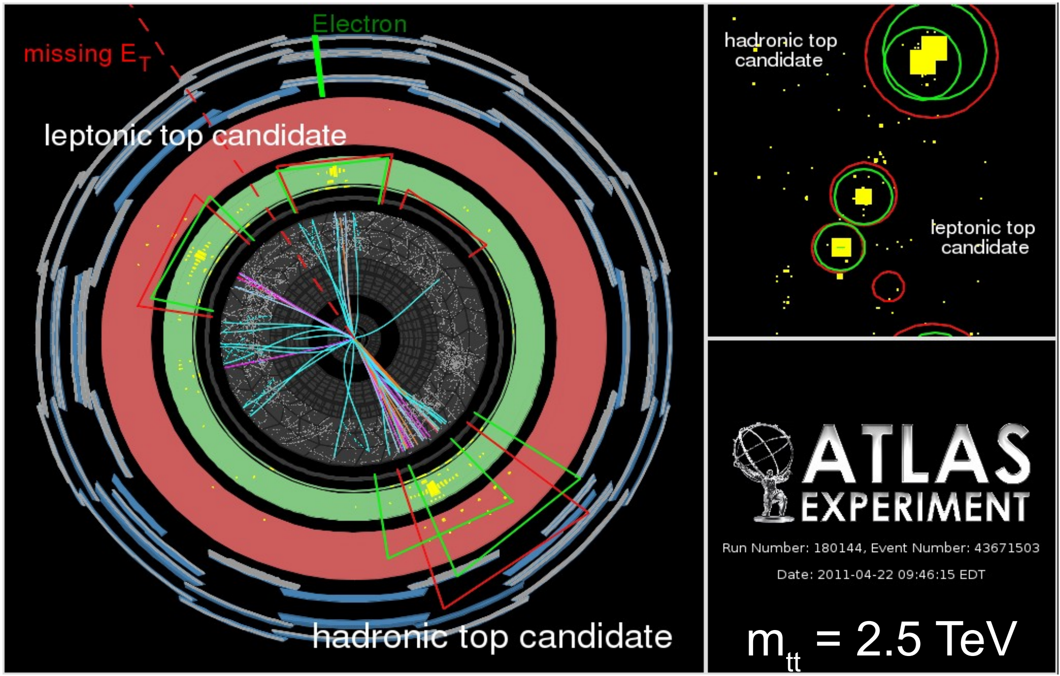
    → Identification of a single → Fat jet for the had top decay
  - Search of exotic heavy quarks (b’b’->WtWt(l$^{\pm}$+jets)) **1.04 fb^{-1}**

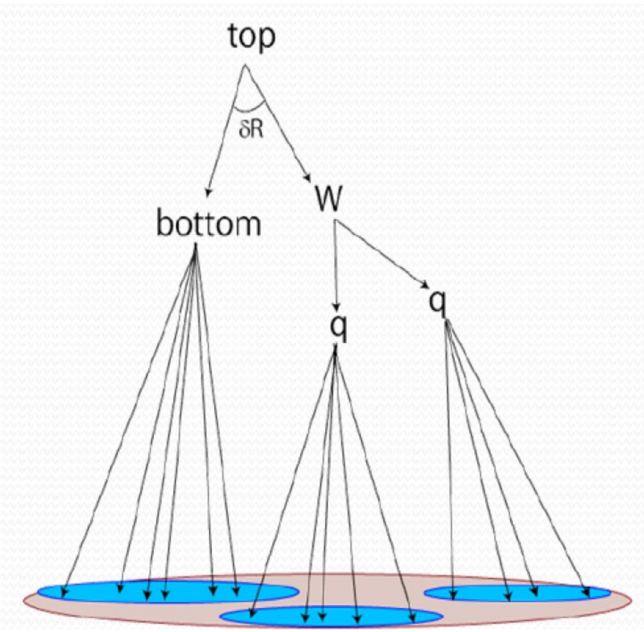
    → Very high p_T hadronicaly decay W boson + high jet multiplicity

New

2.05 fb^{-1}

Search for $t\bar{t}$ resonances in l+jets events with highly boosted top quarks





Selection:

- **t → Wb → b qq**
  - Rec and iso of highly boosted hadronicaly decay of t → single "fat jet"
  - m_j>100GeV & p_T>250 GeV
- **t → Wb → blν**
  - Jet p_T>30 GeV
  - l and jet collimated : $0.1 < \Delta R(l,j) < 1.5$

e channel: $E_T^{miss} > 35$ GeV and $m_T > 25$ GeV & μ channel: $E_T^{miss} > 20$ GeV and $E_t^{miss} + m_T > 60$ GeV

New

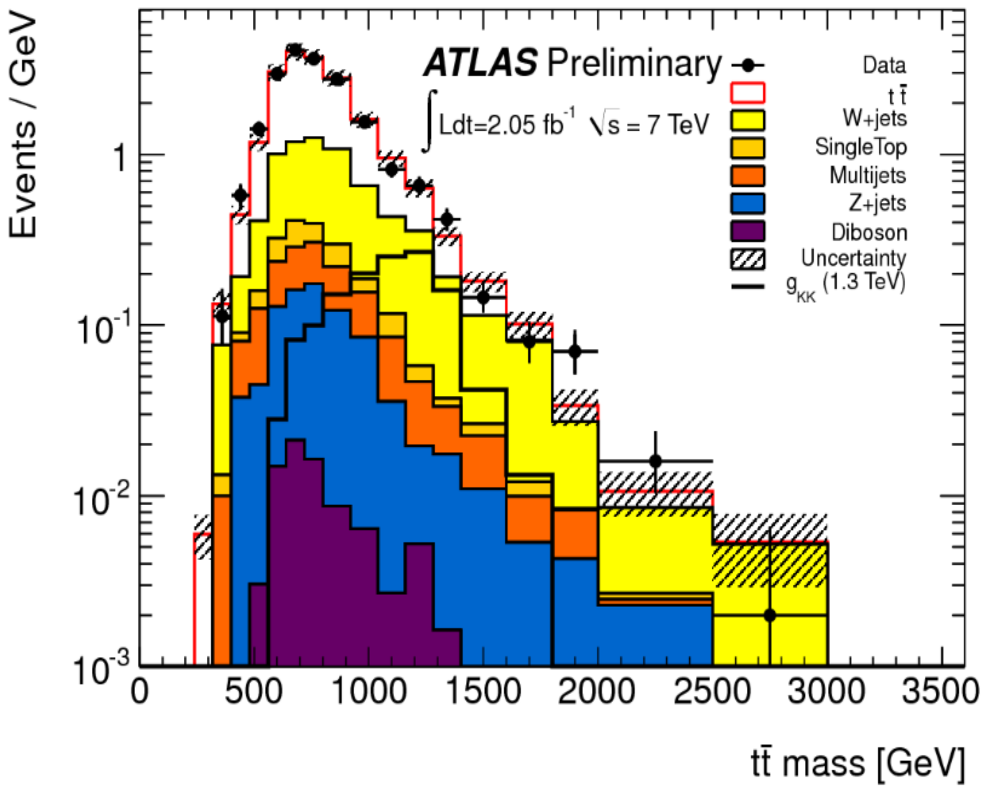
2.05 fb^{-1}

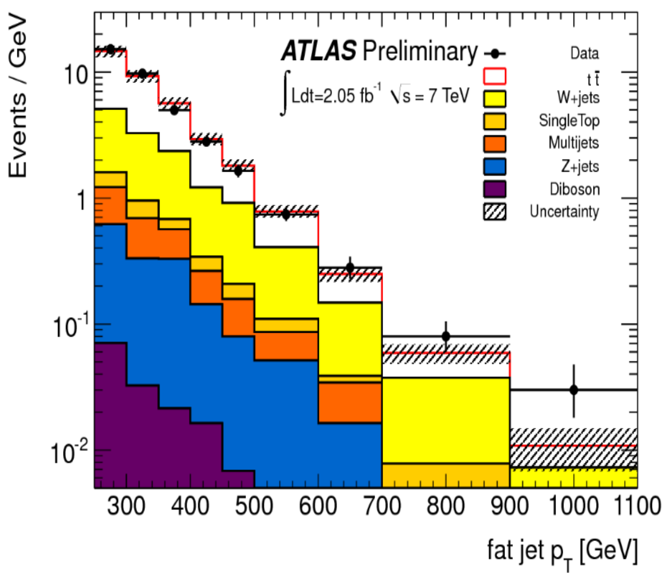
$t\bar{t}$ invariant mass (l+jets channel)

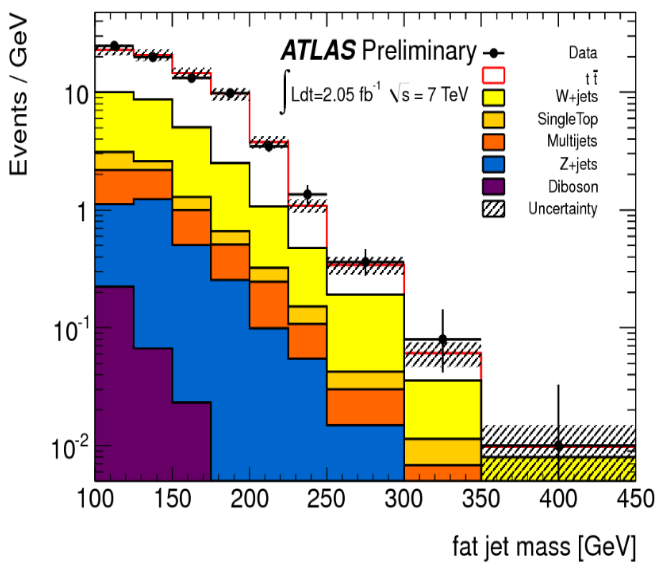
Main backgrounds:

- $t\bar{t}$, single top (MC@NLO)
- W+jets (ALPGEN and normalized to Data)
- QCD multi-jet (fake lepton) estimated using data-driven template

$t\bar{t}$ system reconstructed added 4-momenta of the semileptonic and hadronic top candidates







Good agreement data and expectation

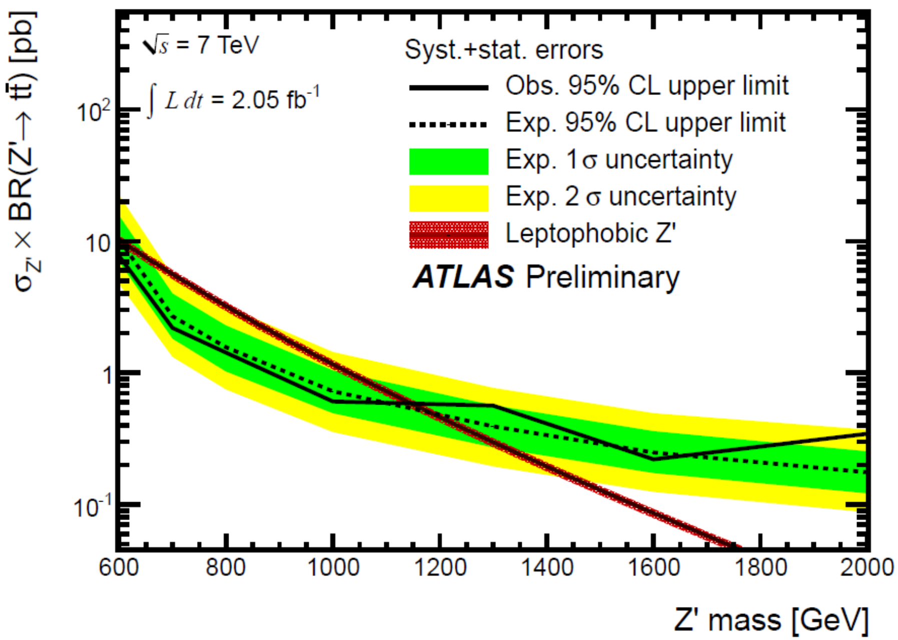
New

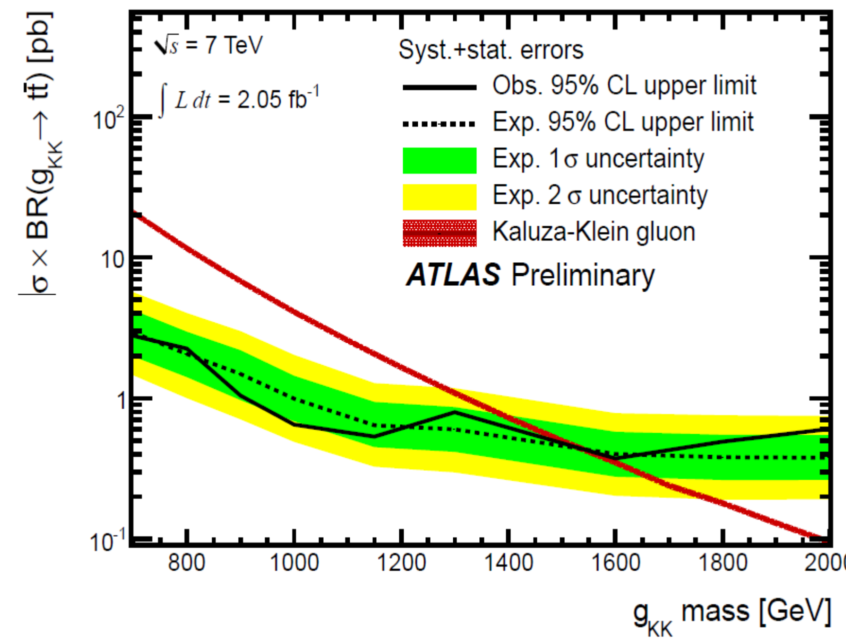
$2.05\ fb^{-1}$

$t\bar{t}$ resonances Limit results

Scenarios for production of $t\bar{t}$

- narrow resonances: via leptophobic Z
- wide resonances: via Kaluza-Klein gluon g_{KK} (Randall-Sundrum models)





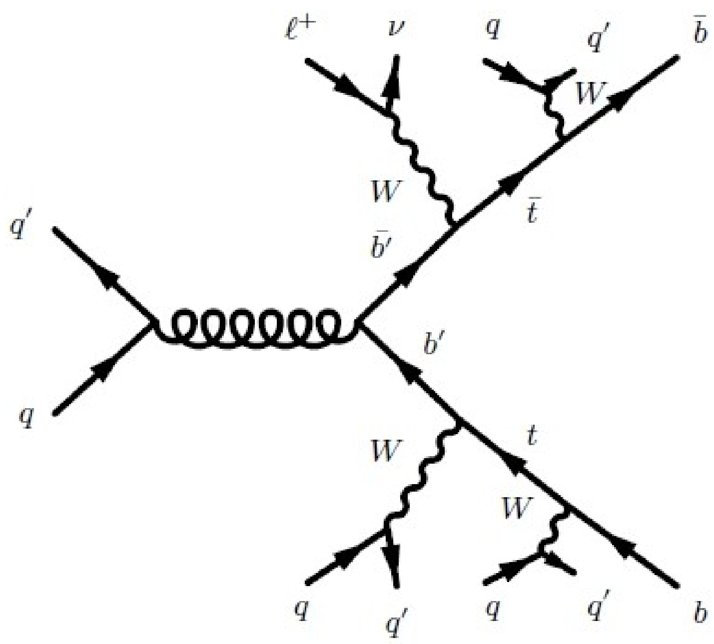
Bayesian 95 C.L Limits on m_{tt} variable:

- **650 GeV < $m_{Z''}$ < 1.2 TeV**
- **m_{gKK} < 1.5 TeV**

__Big improvement__ wrt the search in "mostly resolved topology"
→ $m_{Z''}$ < 860 GeV and m_{gKK} < 1.02 TeV

Search of exotic heavy quarks

b'b'→ WtWt → $l^{\pm}\nu$+jets



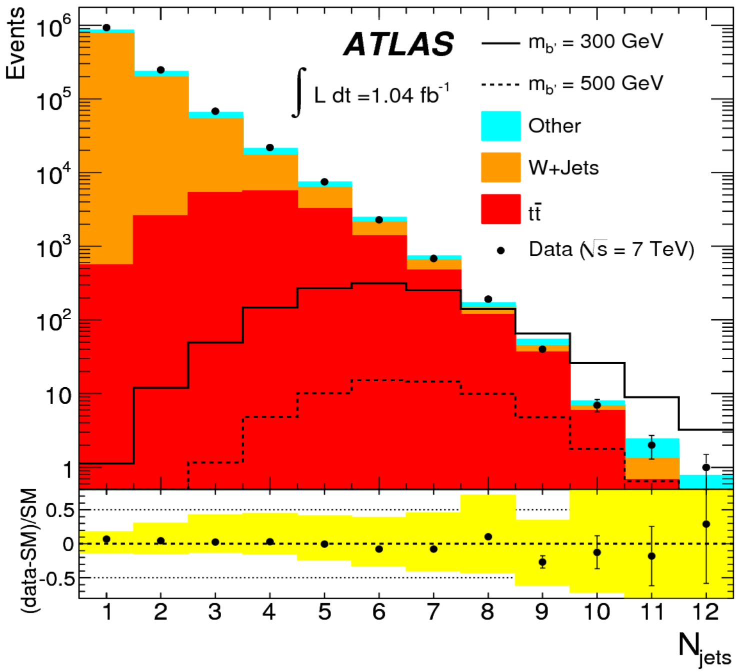
Signature: l + E_T^{miss} + ≥6 jets (l=e,μ)

Event selection:

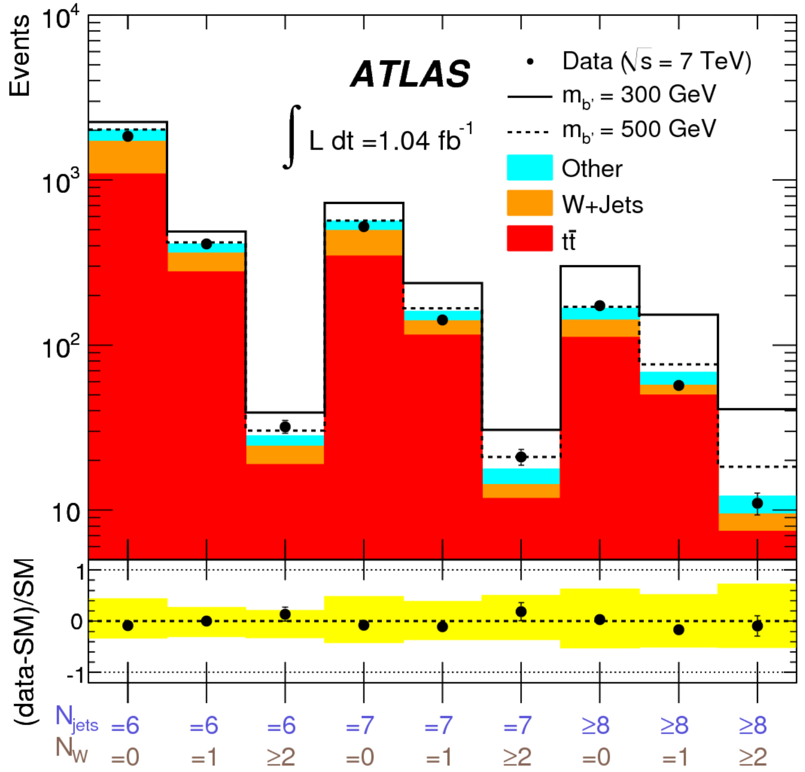
- =1 e/μ, $p_T(e)$>25 GeV, $p_T(\mu)$>20 GeV
- e(μ)+jets: E_T^{miss}>35(20) GeV
- E_T^{miss}+$M_T(W)$>60 GeV
- ≥6 jets with p_T>25 GeV, |η|<2.5

Strategy:

- High jet multiplicity requirement to suppress background .
- Identify **high-p_T W** →qq bosons via invariant mass of *nearby jets (ΔR <0.1)* 70 GeV < m_{jj}< 100 GeV
  - 80% efficiency for energetic W



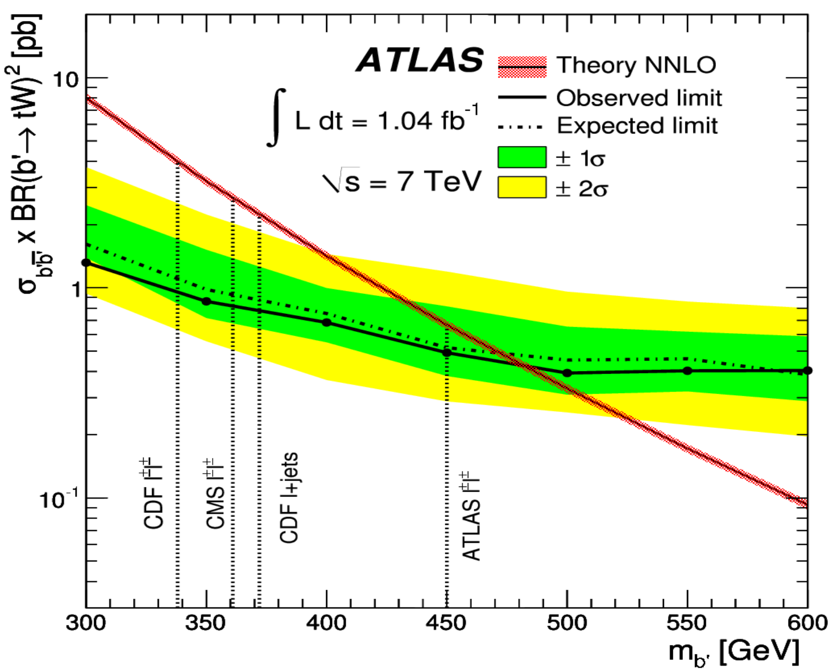
Results: b'b'→ WtWt → $l^{\pm}\nu$+jets



Observable:

- distribution of number of hadronic W(q) boson candidates (0,1,≥2) in 3 different N_{jet} bins (6, 7, ≥8).

Data in good agreement with bkg expectation

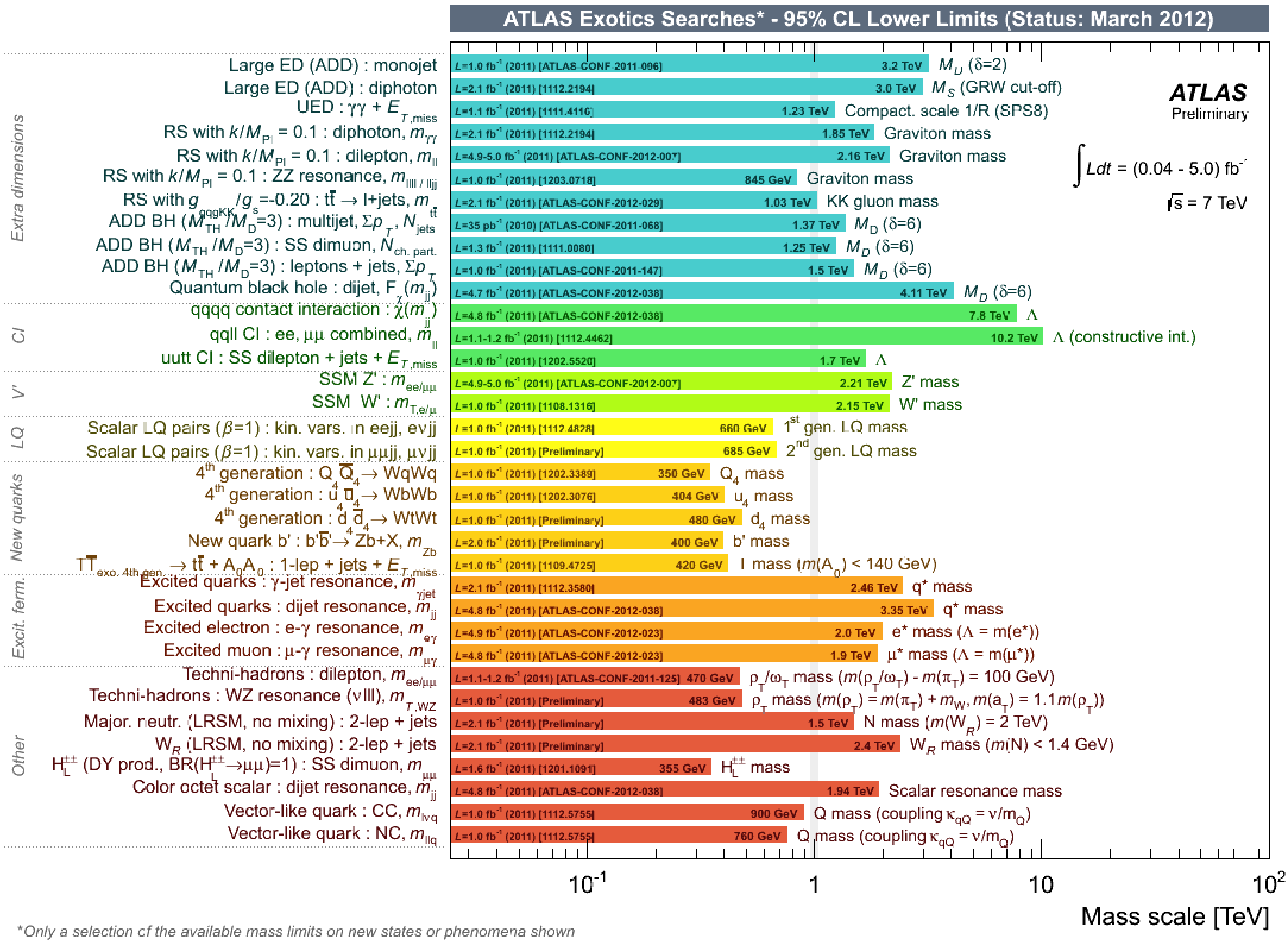


CLs limit @95% C.L.
Assume BR(b' → Wt)=1
$m_{b'}$>480GeV (470GeV expected)

Summary and conclusion

- No evidence of new physics in jets and boosted object final state at ATLAS, but wide range of exotic searches are done.
  - *Set limits on a vast variety of particular models*
  - *model-independent limits*
- Results shown use mostly 1 to 2 fb^{-1} and $\sqrt{s}$ = 7 TeV
  - *More results to come with complete 2011 dataset (5 fb^{-1})*
- Prospects for 2012 Data: $\sqrt{s}$ = 8 TeV
  - Entering era of "boosted top" and fully boosted approach
- For further details, see:
  - ATLAS Exotics results:
    https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults

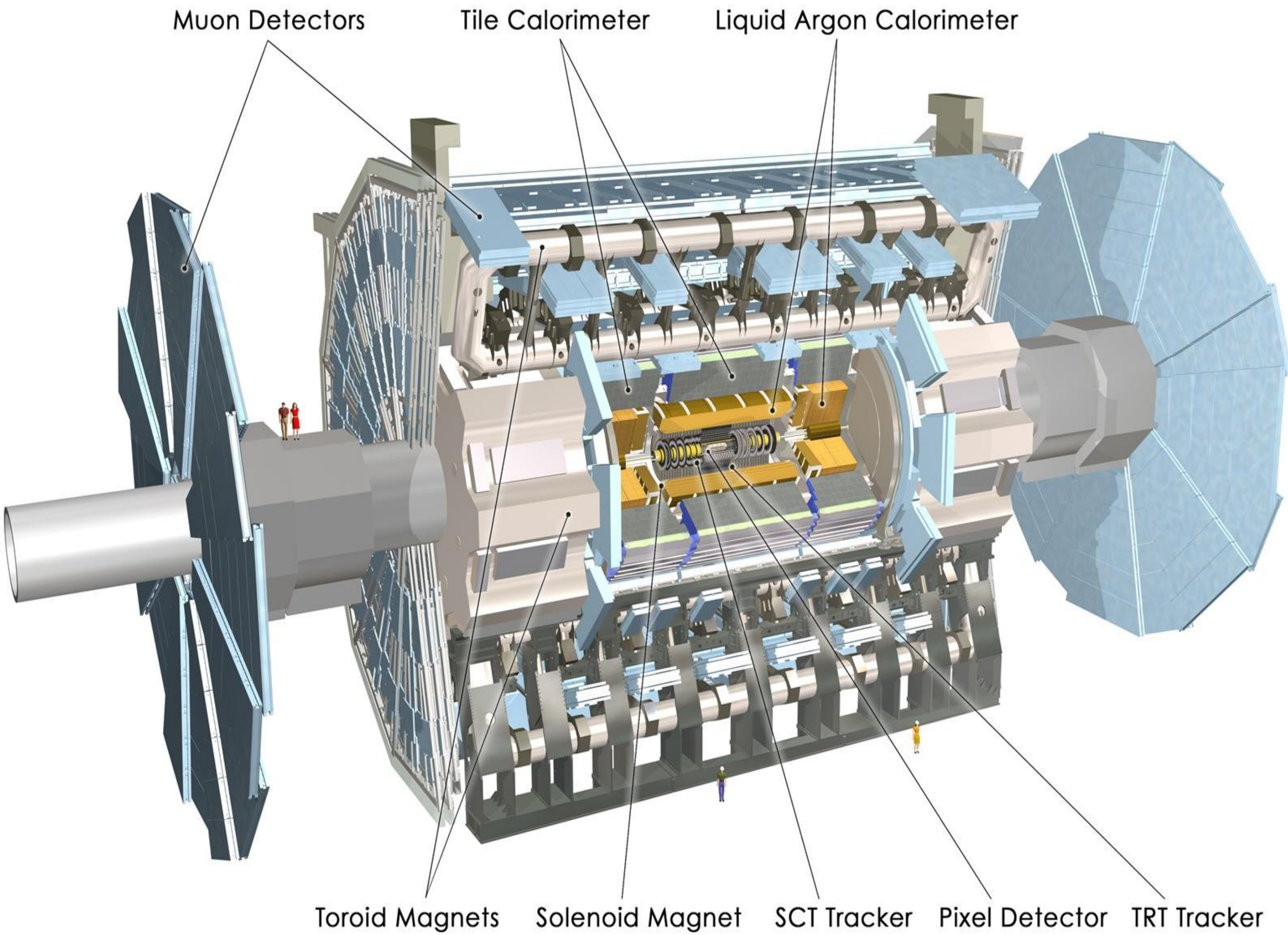
Thanks!



ATLAS Exotics Searches* - 95% CL Lower Limits (Status: March 2012)
ATLAS
Preliminary
∫Ldt = (0.04 - 5.0) fb^-1
√s = 7 TeV
Extra dimensions
Large ED (ADD) : monojet
L=1.0 fb^-1 (2011) [ATLAS-CONF-2011-096]
3.2 TeV
M_D (δ=2)
Large ED (ADD) : diphoton
L=2.1 fb^-1 (2011) [1112.2194]
3.0 TeV
M_S (GRW cut-off)
UED : γγ + E_T,miss
L=1.1 fb^-1 (2011) [1111.4116]
1.23 TeV
Compact. scale 1/R (SPS8)
RS with k/M_Pl = 0.1 : diphoton, m_γγ
L=2.1 fb^-1 (2011) [1112.2194]
1.85 TeV
Graviton mass
RS with k/M_Pl = 0.1 : dilepton, m_ll
L=4.9-5.0 fb^-1 (2011) [ATLAS-CONF-2012-007]
2.16 TeV
Graviton mass
RS with k/M_Pl = 0.1 : ZZ resonance, m_llll / lljj
L=1.0 fb^-1 (2011) [1203.0718]
845 GeV
Graviton mass
RS with g_qqgKK/g_s=-0.20 : tt̄ → l+jets, m_tt
L=2.1 fb^-1 (2011) [ATLAS-CONF-2012-029]
1.03 TeV
KK gluon mass
ADD BH (M_TH/M_D=3) : multijet, Σp_T, N_jets
L=35 pb^-1 (2010) [ATLAS-CONF-2011-068]
1.37 TeV
M_D (δ=6)
ADD BH (M_TH/M_D=3) : SS dimuon, N_ch. part.
L=1.3 fb^-1 (2011) [1111.0080]
1.25 TeV
M_D (δ=6)
ADD BH (M_TH/M_D=3) : leptons + jets, Σp_T
L=1.0 fb^-1 (2011) [ATLAS-CONF-2011-147]
1.5 TeV
M_D (δ=6)
Quantum black hole : dijet, F_χ(m_jj)
L=4.7 fb^-1 (2011) [ATLAS-CONF-2012-038]
4.11 TeV
M_D (δ=6)
CI
qqqq contact interaction : χ(m_jj)
L=4.8 fb^-1 (2011) [ATLAS-CONF-2012-038]
7.8 TeV
Λ
qqll CI : ee, μμ combined, m_ll
L=1.1-1.2 fb^-1 (2011) [1112.4462]
10.2 TeV
Λ (constructive int.)
uutt CI : SS dilepton + jets + E_T,miss
L=1.0 fb^-1 (2011) [1202.5520]
1.7 TeV
Λ
V'
SSM Z' : m_ee/μμ
L=4.9-5.0 fb^-1 (2011) [ATLAS-CONF-2012-007]
2.21 TeV
Z' mass
SSM W' : m_T,e/μ
L=1.0 fb^-1 (2011) [1108.1316]
2.15 TeV
W' mass
LQ
Scalar LQ pairs (β=1) : kin. vars. in eejj, eνjj
L=1.0 fb^-1 (2011) [1112.4828]
660 GeV
1st gen. LQ mass
Scalar LQ pairs (β=1) : kin. vars. in μμjj, μνjj
L=1.0 fb^-1 (2011) [Preliminary]
685 GeV
2nd gen. LQ mass
New quarks
4th generation : Q_4 Q̄_4 → WqWq
L=1.0 fb^-1 (2011) [1202.3389]
350 GeV
Q_4 mass
4th generation : u_4 ū_4 → WbWb
L=1.0 fb^-1 (2011) [1202.3076]
404 GeV
u_4 mass
4th generation : d_4 d̄_4 → WtWt
L=1.0 fb^-1 (2011) [Preliminary]
480 GeV
d_4 mass
New quark b' : b'b̄' → Zb+X, m_Zb
L=2.0 fb^-1 (2011) [Preliminary]
400 GeV
b' mass
TT̄_exo. 4th gen. → tt̄ + A_0A_0 : 1-lep + jets + E_T,miss
L=1.0 fb^-1 (2011) [1109.4725]
420 GeV
T mass (m(A_0) < 140 GeV)
Excit. ferm.
Excited quarks : γ-jet resonance, m_γjet
L=2.1 fb^-1 (2011) [1112.3580]
2.46 TeV
q* mass
Excited quarks : dijet resonance, m_jj
L=4.8 fb^-1 (2011) [ATLAS-CONF-2012-038]
3.35 TeV
q* mass
Excited electron : e-γ resonance, m_eγ
L=4.9 fb^-1 (2011) [ATLAS-CONF-2012-023]
2.0 TeV
e* mass (Λ = m(e*))
Excited muon : μ-γ resonance, m_μγ
L=4.8 fb^-1 (2011) [ATLAS-CONF-2012-023]
1.9 TeV
μ* mass (Λ = m(μ*))
Other
Techni-hadrons : dilepton, m_ee/μμ
L=1.1-1.2 fb^-1 (2011) [ATLAS-CONF-2011-125]
470 GeV
ρ_T/ω_T mass (m(ρ_T/ω_T) - m(π_T) = 100 GeV)
Techni-hadrons : WZ resonance (νlll), m_T,WZ
L=1.0 fb^-1 (2011) [Preliminary]
483 GeV
ρ_T mass (m(ρ_T) = m(π_T) + m_W, m(a_T) = 1.1 m(ρ_T))
Major. neutr. (LRSM, no mixing) : 2-lep + jets
L=2.1 fb^-1 (2011) [Preliminary]
1.5 TeV
N mass (m(W_R) = 2 TeV)
W_R (LRSM, no mixing) : 2-lep + jets
L=2.1 fb^-1 (2011) [Preliminary]
2.4 TeV
W_R mass (m(N) < 1.4 GeV)
H_L^±± (DY prod., BR(H_L^±±→μμ)=1) : SS dimuon, m_μμ
L=1.6 fb^-1 (2011) [1201.1091]
355 GeV
H_L^±± mass
Color octet scalar : dijet resonance, m_jj
L=4.8 fb^-1 (2011) [ATLAS-CONF-2012-038]
1.94 TeV
Scalar resonance mass
Vector-like quark : CC, m_lνq
L=1.0 fb^-1 (2011) [1112.5755]
900 GeV
Q mass (coupling κ_qQ = v/m_Q)
Vector-like quark : NC, m_llq
L=1.0 fb^-1 (2011) [1112.5755]
760 GeV
Q mass (coupling κ_qQ = v/m_Q)
10^-1
1
10
10^2
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown

Back-up

The ATLAS detector



Dijet analysis main systematic uncertainty

	Search phase	Limit setting phase
Dijet mass analysis		JES Luminosity Acceptance Fit
Angular analyses	JES Renormalization scale Factorization scale PDF	JES Renormalization scale Factorization scale PDF

Dijet analysis Limits results

For a large number of model the 95% C.L. lower limits on the masses and energy scales

Model, and Analysis Strategy	95% C.L. Limits (TeV)	
	Expected	Observed
Excited quark, mass of q^*		
Resonance in m_{jj}	3.09	3.35
Resonance in $F_\chi(m_{jj})$	2.97	2.58
Colour octet scalar, mass of s8		
Resonance in m_{jj}	1.94	1.94
Quantum Black Hole for $n = 6$, M_D		
$F_\chi(m_{jj})$	4.14	4.11
11-bin χ , $m_{jj} > 2.6$ TeV	4.23	3.96
Contact interaction, Λ, destructive interference		
$F_\chi(m_{jj})$	8.2	7.6
11-bin χ , $m_{jj} > 2.6$ TeV	8.7	7.8

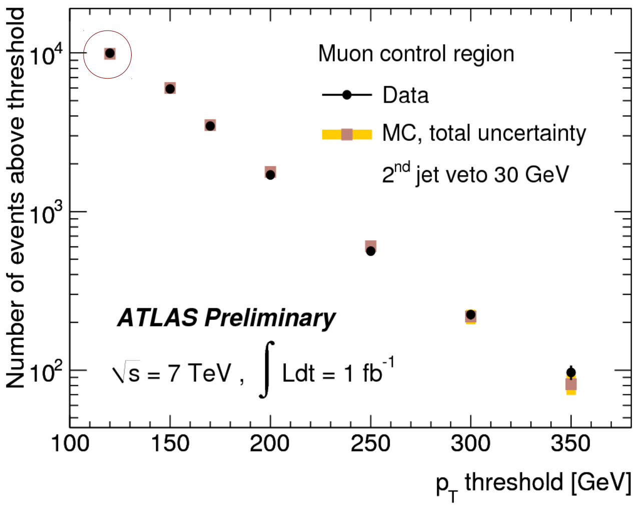
γ-jet analysis main systematic uncertainty

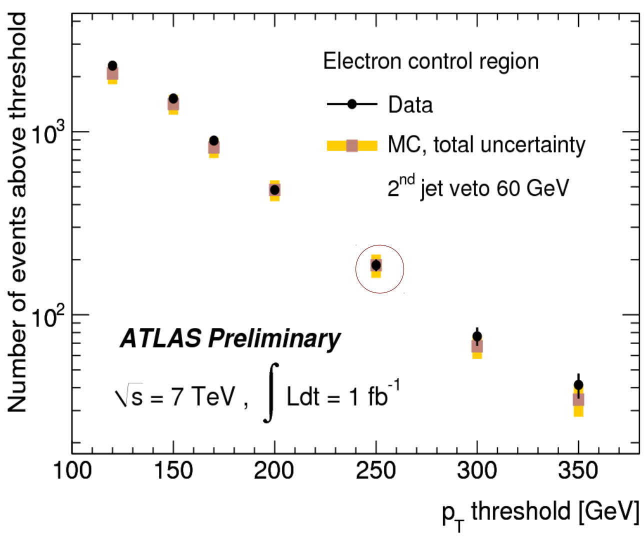
The major source of systematic evaluated for this analysis come from:

- Luminosity ⊕ γ-ID = 3.7% ⊕ 2.0%
- Bkg Fit function uncertainty
  - Parametrization bias (10% @ 2 TeV)
- Jet Energy Scale (2 − 4%)
- Jet Energy Resolution (5–15%)
- γ-Energy Scale (0.5–1.5%)

Jet + missing E_T bkg estimate

- **Z/W+jets:** dominant contribution to the bkg → MC estimate + rescaling from data.
- **Z → νν** irreducible and ttbar→ MC
- **Multi-jets** bkg contribution → data-driven
- **Non collision bkg** → data



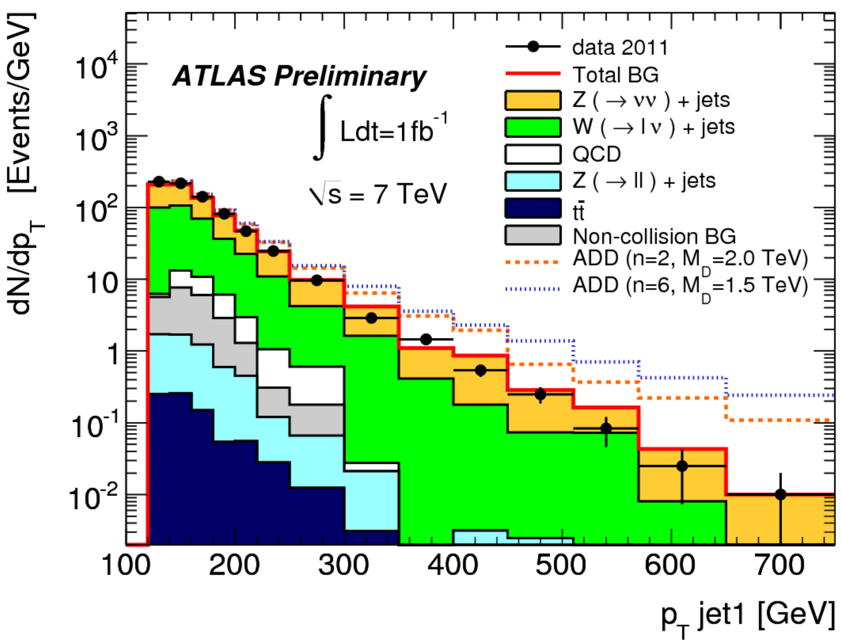


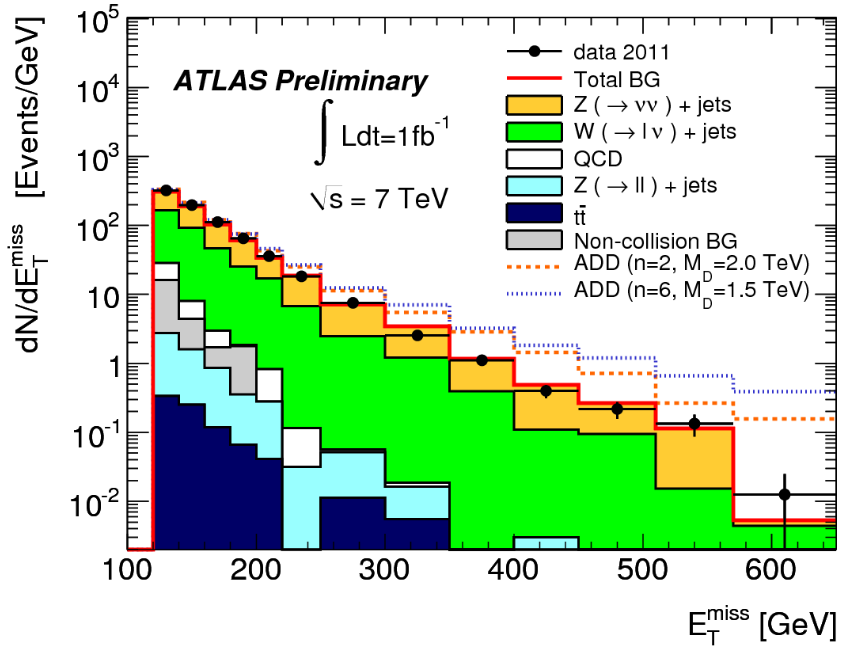
- *Z/W+jets bkg* estimate with ALPGEN MC (NNLO cross-section) *rescaled using the data control sample obtained inverting the lepton veto requirement.*
- Multi-jets bkg contribution → *data-driven dijets-enriched samples extrapolating the second jet p_T in the signal region.*

	Background Predictions ± (stat.) ± (syst.)		
	LowPt Selection	HighPt Selection	veryHighPt selection
$Z(\rightarrow \nu\bar{\nu})$+jets	$7700 \pm 90 \pm 400$	$610 \pm 27 \pm 47$	$124 \pm 12 \pm 15$
$W(\rightarrow \tau\nu)$+jets	$3300 \pm 90 \pm 220$	$180 \pm 16 \pm 22$	$36 \pm 7 \pm 8$
$W(\rightarrow e\nu)$+jets	$1370 \pm 60 \pm 90$	$68 \pm 10 \pm 8$	$8 \pm 1 \pm 2$
$W(\rightarrow \mu\nu)$+jets	$1890 \pm 70 \pm 100$	$113 \pm 14 \pm 9$	$18 \pm 4 \pm 2$
Multi-jets	$360 \pm 20 \pm 290$	$30 \pm 6 \pm 11$	$3 \pm 2 \pm 2$
$Z/\gamma^*(\rightarrow \tau^+\tau^-)$+jets	$59 \pm 3 \pm 4$	$2.0 \pm 0.6 \pm 0.2$	-
$Z/\gamma^*(\rightarrow \mu^+\mu^-)$+jets	$45 \pm 3 \pm 2$	$2.0 \pm 0.6 \pm 0.1$	-
$t\bar{t}$	$17 \pm 1 \pm 3$	$1.7 \pm 0.3 \pm 0.3$	-
γ+jet	-	-	-
$Z/\gamma^*(\rightarrow e^+e^-)$+jets	-	-	-
Non-collision Background	$370 \pm 40 \pm 170$	$8.0 \pm 3.3 \pm 4.1$	$4.0 \pm 3.2 \pm 2.1$
Total Background	$15100 \pm 170 \pm 680$	$1010 \pm 37 \pm 65$	$193 \pm 15 \pm 20$
Events in Data (1.00 fb^{-1})	15740	965	167

Jet + missing E_T Results

- Low-p_T signal region



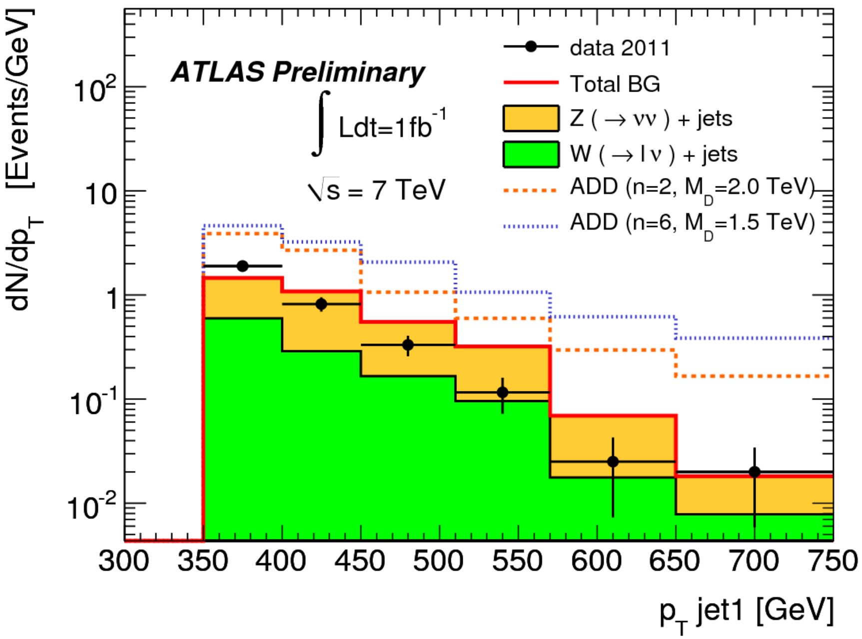


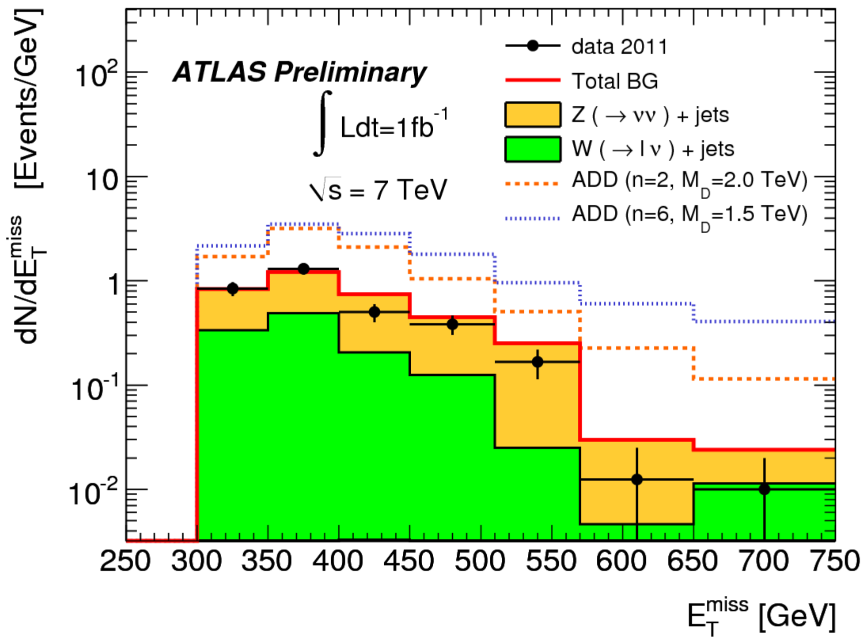
Good agreement data and MC prediction

	Low p_T	High p_T	Very high p_T
Jet p_T >	120 GeV	250 GeV	350 GeV
E_t^{miss} >	120 GeV	220 GeV	300 GeV
Second Jet p_T <	30 GeV	60 GeV	60 GeV

Jet + missing E_T Results

- Very High-p_T signal region





Good agreement data and MC prediction

	Low p_T	**High p_T**	**Very high p_T**
Jet p_T >	120 GeV	250 GeV	350 GeV
E_t^{miss} >	120 GeV	220 GeV	300 GeV
Second Jet p_T <	30 GeV	60 GeV	60 GeV

tt resonance search systematic uncertainty

For the systematic uncertainties none contributing more individually than 15% of the total uncertainty.

- Systematic uncertainties on the normalization of the different backgrounds:
  - Integrated luminosity (3.7%)
  - background normalizations (tt: +7.0 %, single top: 10%, W+jets: 48%, Z+jets: 48%, diboson: 5%, multijet: 50%)

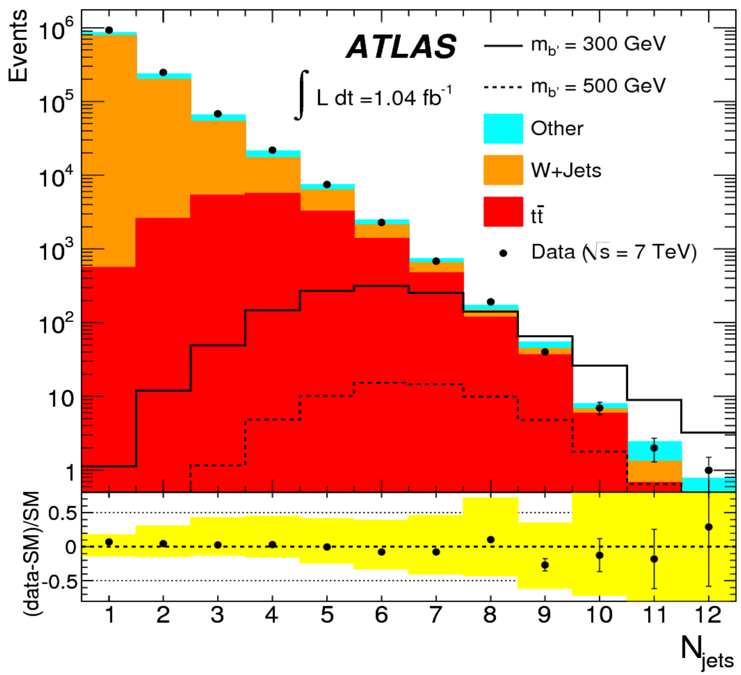
- The dominant shape uncertainties arise from:
  - the b-tagging efficiency (18.9%/16.5% variation in the m_Z = 1TeV signal/background yields)
  - jet energy scale including pileup effects (3.4%/4.2%)
  - modeling of initial and final state radiation (0.9%/8.5%).

Heavy quark search

- Dominant systematic uncertainties:

	Uncertainty on Background
Profiled Uncertainties	
W+jets Normalization	$\pm 5\%$ ($\pm 16\%$)
ISR/FSR	$\pm 12\%$ ($\pm 17\%$)
Jet Energy Resolution	$\pm 3\%$ ($\pm 6\%$)
Jet Reconstruction Efficiency	$\pm 2\%$ ($\pm 3\%$)
Not-profiled Uncertainties	
Jet Energy Scale	$\pm 31\%$
$t\bar{t}$ Simulation Generator	$\pm 6\%$
$t\bar{t}$ Showering Model	$\pm 3\%$

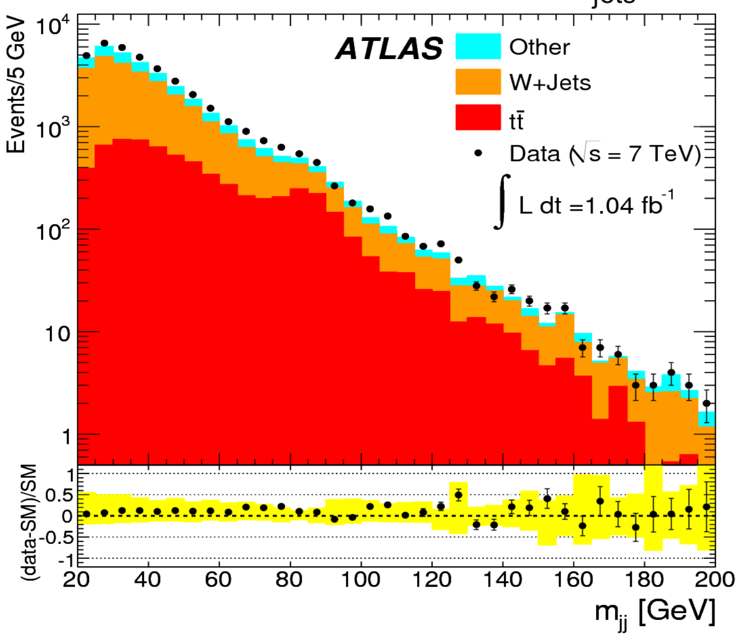
$b'b' \to WtWt \to l^{\pm}\nu$ + jets



Background:

- Dominated by tt+jets (modeled with ALPGEN up to 3 explicit partons).
- W+jets next most important background.

$3 \le N_{jets} \le 5$



Background modeling validated in several signal-depleted control samples: $3 \le N_{jets} \le 5$

- Reconstruct $W \to qq_{bar}$
  - jet pairs within $\Delta R(jj)<1.0$
  - 70 GeV<m(jj)<100 GeV