Top Partners and compositeness

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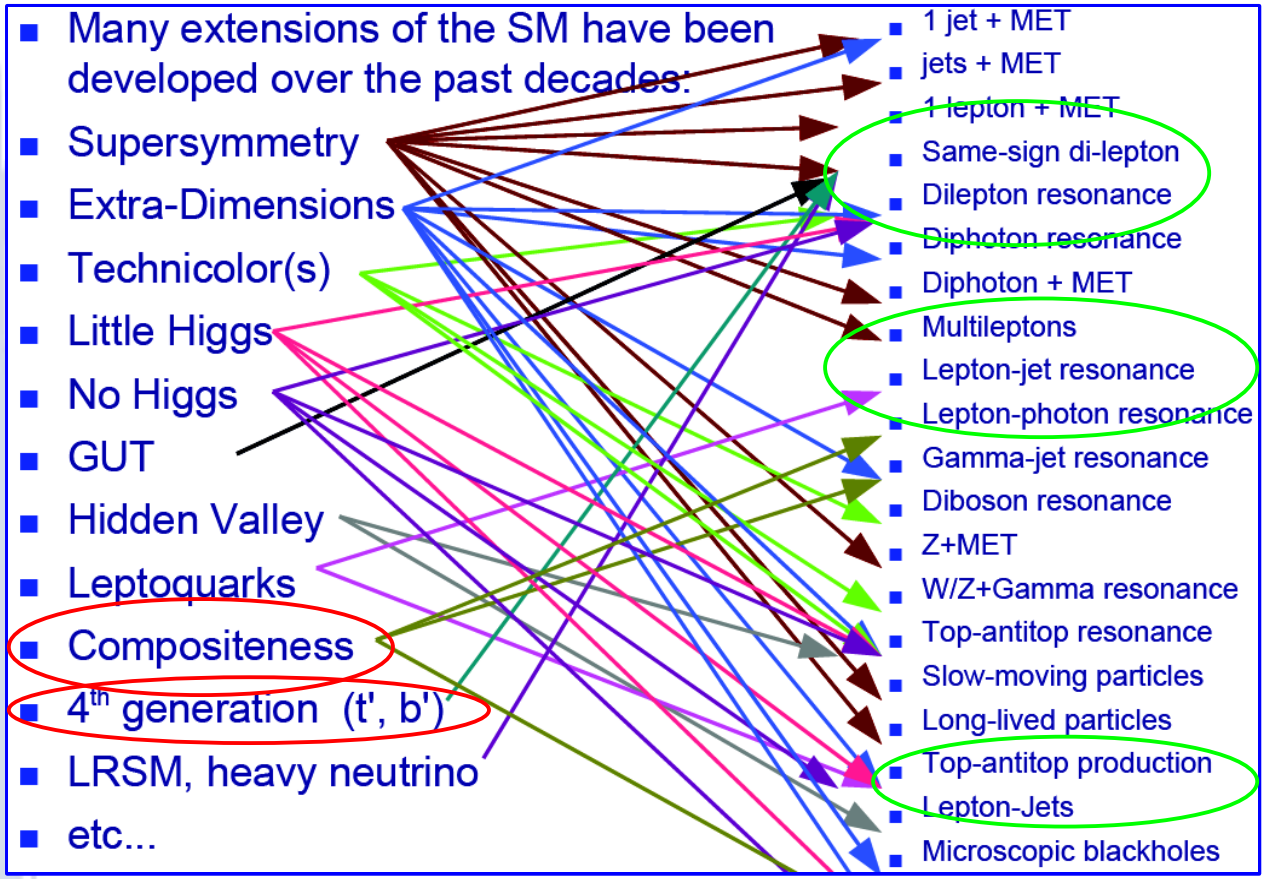
Sergio Grancagnolo[1], Sara Vanini[2]
[1] Humboldt Universitat Zu Berlin
[2]Università di Padova

TOPIC OR SIGNATURES-BASED APPROACH



New physics: observing deviations from predictions

Direct searches:
– kinematic observables or mass of new particles
– Many models and many signatures
– No comprehensive theory
– very good signal to noise

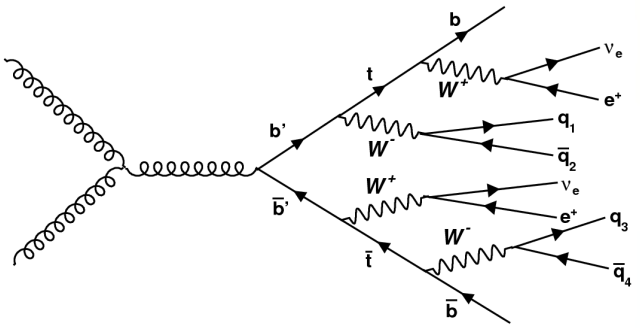
Same final state probing very different models: we will follow mostly a topic-based approach

Signatures:
1. **Single lepton+jets**
2. **Same-sign dileptons**
3. **At least 3 leptons**
4. **Dijets**

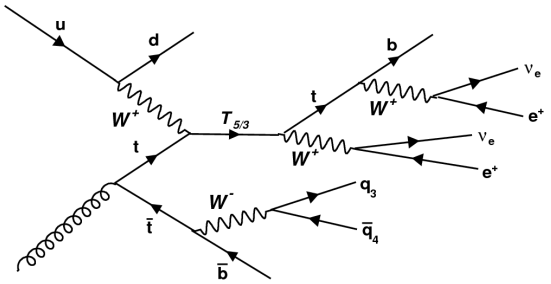
Models
- **t',b', single b'**
- **VLQ, $T_{5/3}$**
- **Excited quarks**
- **Excited leptons**

4th generation extensions

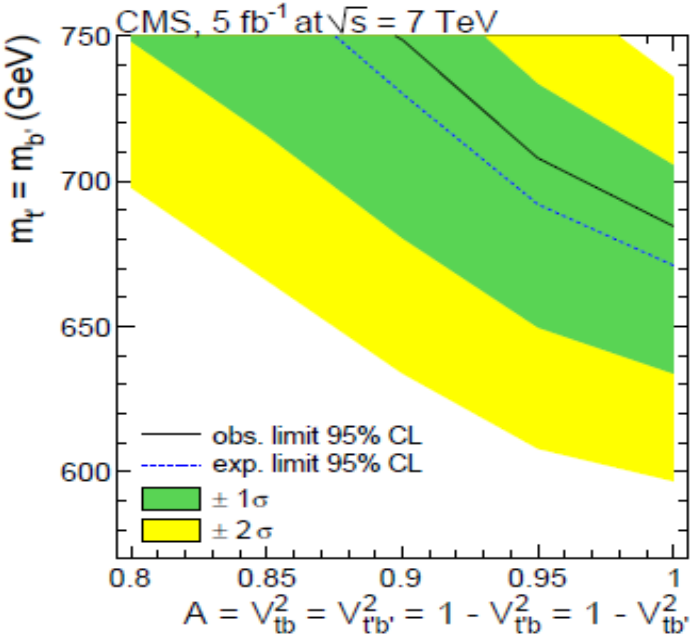
- Simplest and **natural extension of Standard Model**
- Strongly produced, main couplings to third family, **consistent with precision electroweak** measurements
  - **upper bound from QCD** (asymptotic freedom): #families<9
- Chiral 4th generation enhance SM Higgs boson production in gg fusion
  - Suppressed BR(H→γγ)
  - Heavy Dirac neutrino might open invisible H decays
    - Common reduction factor to all BR
  - In accordance with extended Higgs sector
    - Ex. Two-Higgs-Doublet models

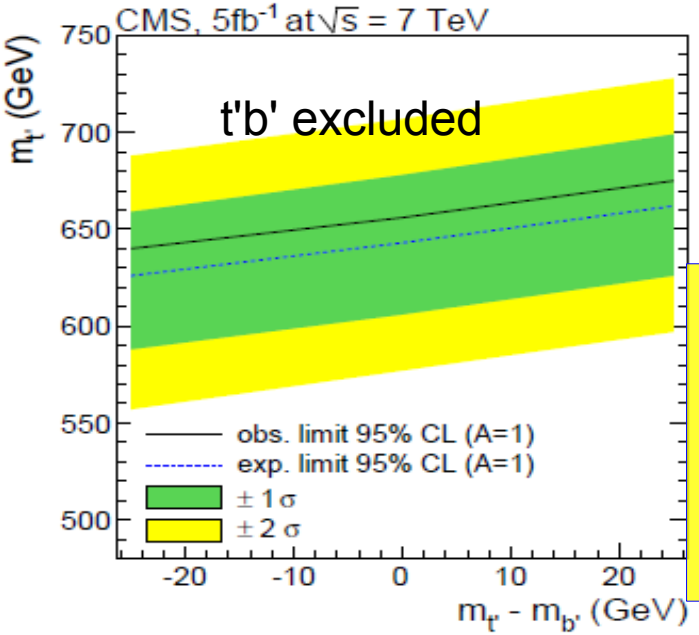


- Vector like quarks, with same chiral transform under EW group
  - Mass terms may appear in $\mathcal{L}$
  - Cancel Higgs quadratic divergences
  - Rich phenomenology: t' → Wb, Zt, Ht
  - May appear as singlet, doublet, triplet with possible -4/3, +5/3 charges



t't̄, b'b̄', t'b, b't, t'b' → ≥ 1 lepton + Jets





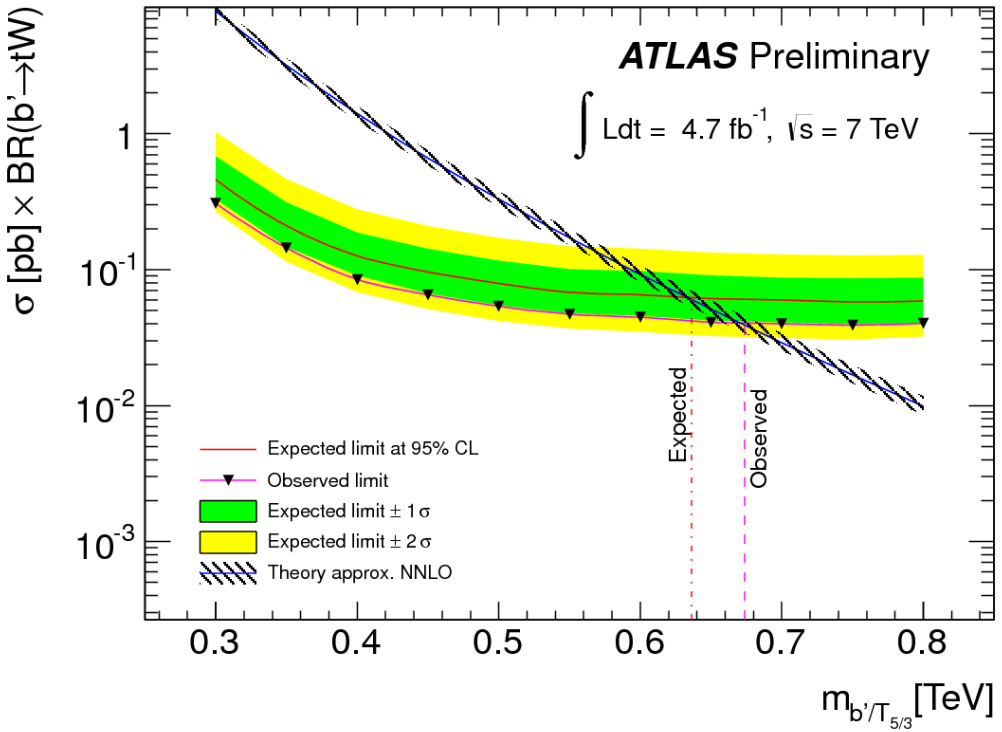
Combined search for single or pair produced t' and b' forth-generation quarks

- **Search for t't̄', b'b̄', t'b, b't, t'b' in pp collisions** at **7 TeV in CMS 2011** data @LHC (luminosity **5.0 fb^{-1}**)
- Considers ≥1 lepton, ≥2 jets, ≥1 b-tagged; S_T fit or counting exp.
- limit on the mass as a function of V_{CKM}^{4x4} parameter $A=|V_{tb}|^2=|V_{t'b'}|^2$ (A>0.66 from single-top σ measurements); $\sigma_{tb'/t'b} \sim 1-A$, $\sigma_{b't'} \sim A$, $\sigma_{tt'/b'b}$ ind. of A
- t' and b' masses degenerate within 25 GeV

CMS EXO 11-098
arXiv:1209.1062v2[hep-ex]
Phys. Rev. D 86 (2012) 112003

- **M > 685 GeV limit on mass-degenerate fourth-generation if A~1**
- **Limit ±20 GeV if mass splitting of 25 GeV**

$T_{5/3}$,b',4 tops in same-sign dileptons



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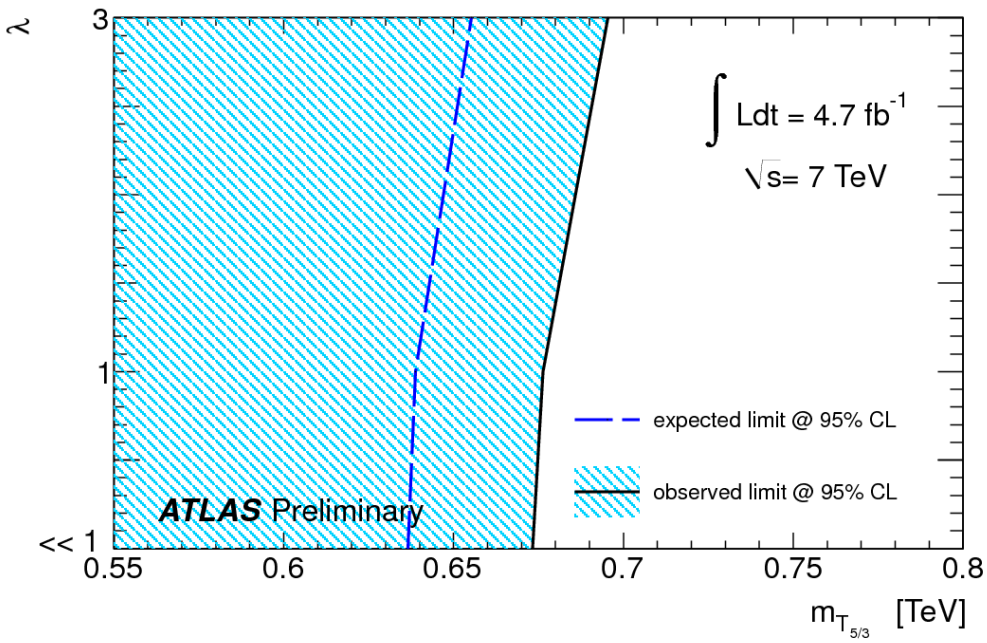
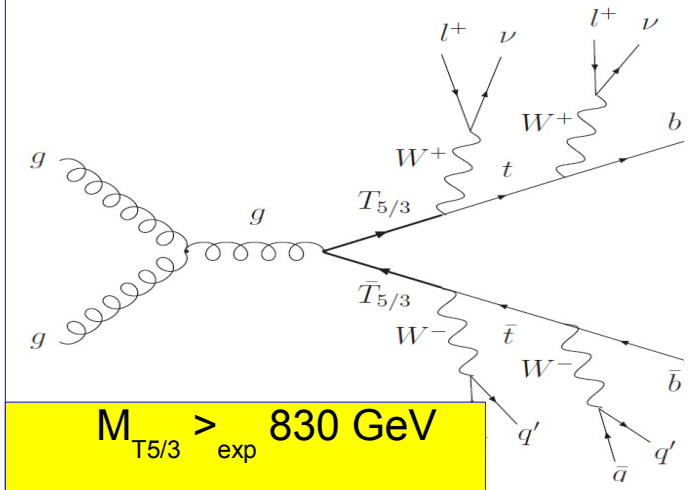


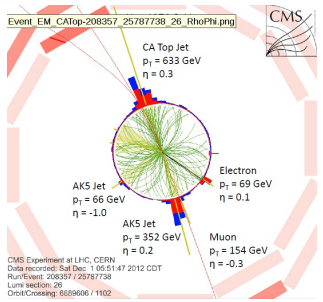
Constrained parameter	95% C.L. limits Expected	Observed
b' / $T_{5/3}$ pair production		
b' mass or $T_{5/3}$ mass for $\lambda \ll 1$	> 0.64 TeV	> 0.67 TeV
$T_{5/3}$ single and pair production		
$T_{5/3}$ mass for $\lambda = 1$	> 0.64 TeV	> 0.68 TeV
$T_{5/3}$ mass for $\lambda = 3$	> 0.66 TeV	> 0.70 TeV
Four top quark event production		
Four top quark production cross-section	< 90 fb	< 61 fb

$T_{5/3}\bar{T}_{\bar{5/3}} \rightarrow tW^{-}\bar{t}W^{+} \rightarrow$ 2 leptons + Jets

Forth generation model heavy partners of the top $T_{5/3}$ and $B_{-1/3}$

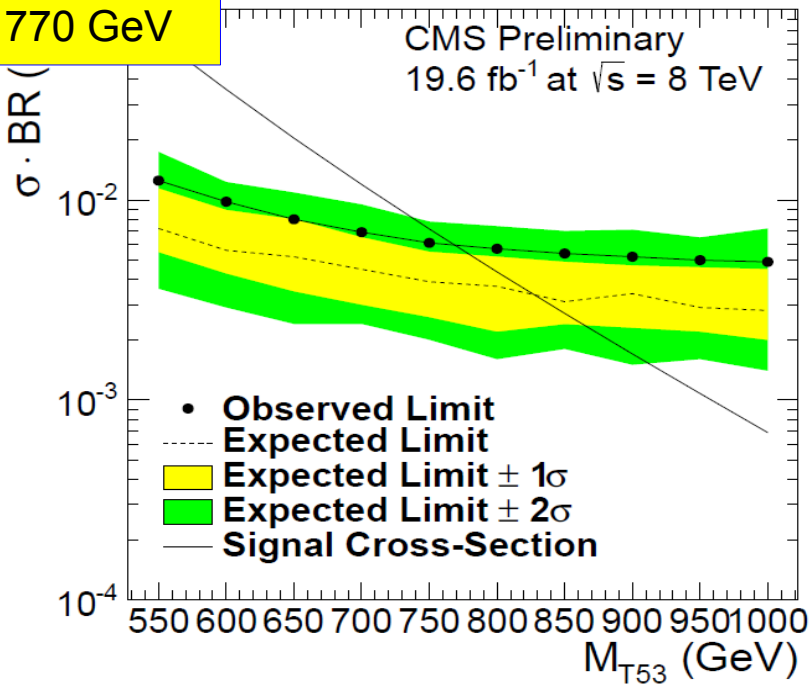
- Dirac particle (no contribution to Higgs boson cross-section, not excluded by recent Higgs like resonances)
- Mass of $B_{-1/3}$ > Mass of $T_{5/3}$
- Mass of $T_{5/3}$ ~ [300 GeV, 1 TeV]
- BR($T_{5/3}$ ->tW) = 100%





$M_{T5/3} >_{exp}$ 830 GeV

$M_{T5/3} >_{obs}$ 770 GeV



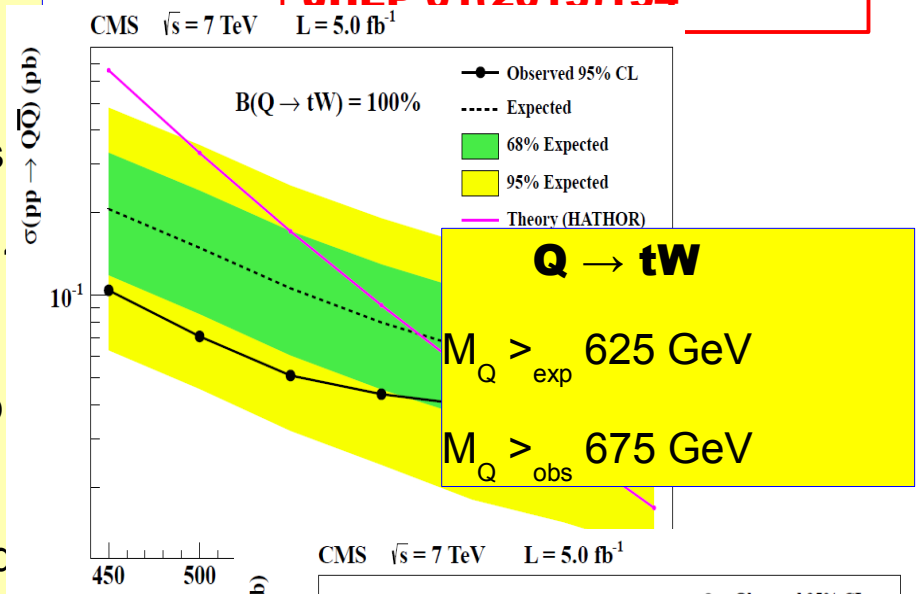
- Heavy 5/3 charge top partners search signal in pp collisions at **8 TeV in CMS 2012** data @LHC (luminosity **19.6 fb^{-1}**)
- **Signature: 2 same sign leptons** (electrons and muons), jets, and missing energy
- **Background:** prompt leptons dominated by WZ (also $W^{\pm}W^{\pm}$,ttW,ttZ,WWW); non-prompt leptons (tt,Wjets,Zjets) opposite charge leptons wrong-charge reconstructed (60% for e, negligible for mu)

CMS PAS B2G-12-012

$Q\bar{Q}\rightarrow tW^{-}\bar{t}W^{+}$ or $t\bar{Z}\bar{t}Z\rightarrow$..... 1 Lepton + Jets

- Pair production of heavy quarks QQ search signal in pp collisions at 7 TeV in **CMS 2012** data @LHC (luminosity **5.0 fb^{-1}**)
- Decay chains: **$Q\bar{Q}\rightarrow tW^{-}\bar{t}W^{+}\rightarrow bW^{+}W^{-}\bar{b}W^{-}W^{+}$**, **$Q\bar{Q}\rightarrow t\bar{Z}\bar{t}Z\rightarrow bW^{+}Z\bar{b}W^{-}Z$** : 1 W decays leptonically, all the others bosons decay in quark-antiquark pairs
- **Signature: 1 lepton** (electron or muon), at least 4 jets with large p_T (at least 1 b-like) and missing p_T
- **Background**: $t\bar{t}$, Wjets, Zjets, dibosons, single top, multijets. Low jet multiplicity, small lepton and jet p_T
- To test presence of new physics signal $S_T = \sum p_T$ and missing p_T are used; fitting the data to the distribution of S_T as a function of jet multiplicity

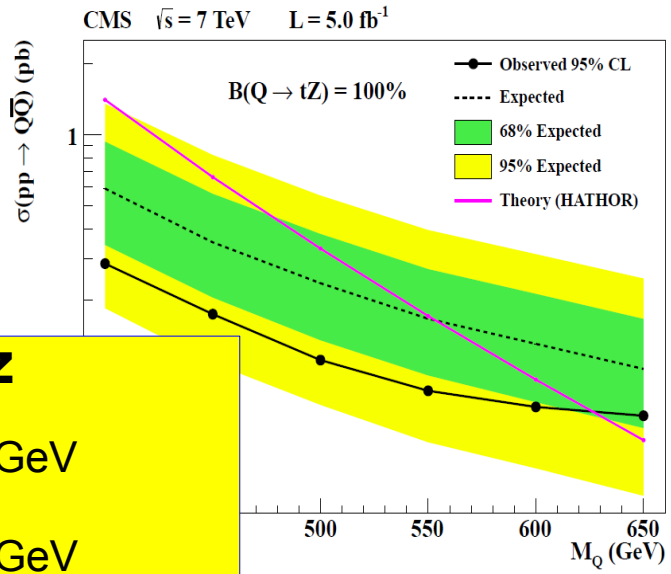
CMSB2G-12-004
arXiv:1210.7471v2[hep-ex]
JHEP 01(2013)154



Q → tW

$M_Q >_{exp}$ 625 GeV

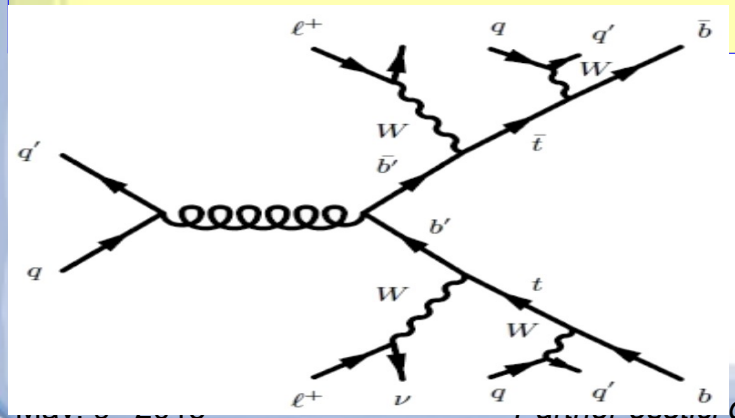
$M_Q >_{obs}$ 675 GeV



Q → tZ

$M_Q >_{exp}$ 550 GeV

$M_Q >_{obs}$ 625 GeV

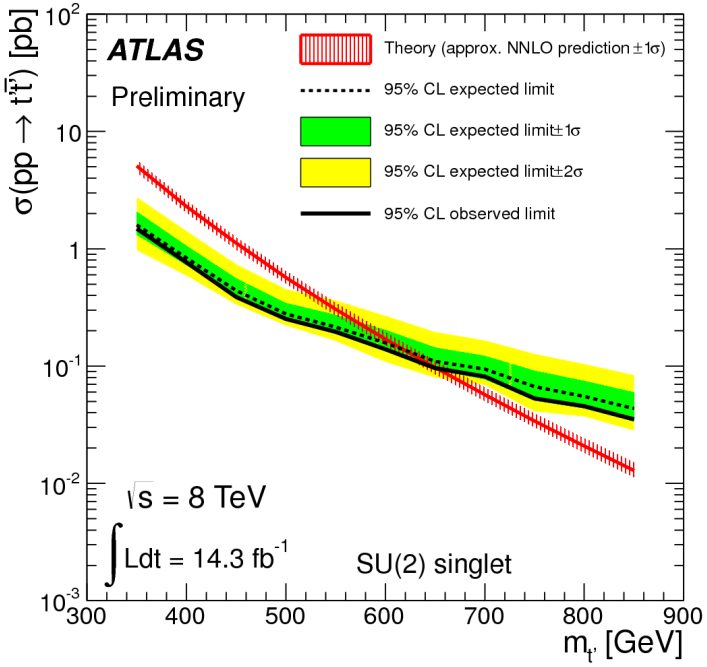


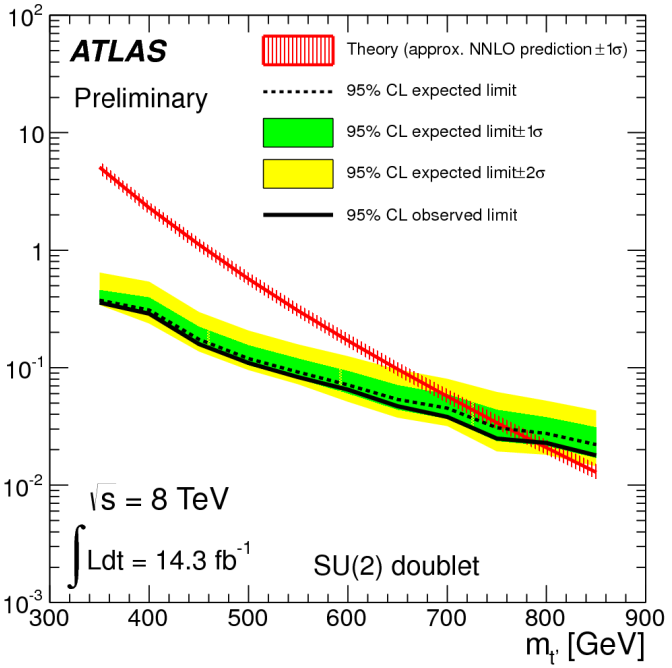
ATLAS-CONF-2013-018

t'→Ht (l+jets)

Analysis: sensitive to channels HtH$\bar{t}$, ZtH$\bar{t}$, WbH$\bar{t}$, ZtZ$\bar{t}$, WbZ$\bar{t}$

- ≥ 6 jets, ≥ 2 b-tagged jets
- Three signal regions based on b-tags (=2, =3, ≥ 4)
- Simultaneous fit to the three H_T distributions to determine scaling factors for $t\bar{t}$ + light jets and $t\bar{t}$ + heavy-flavor jets

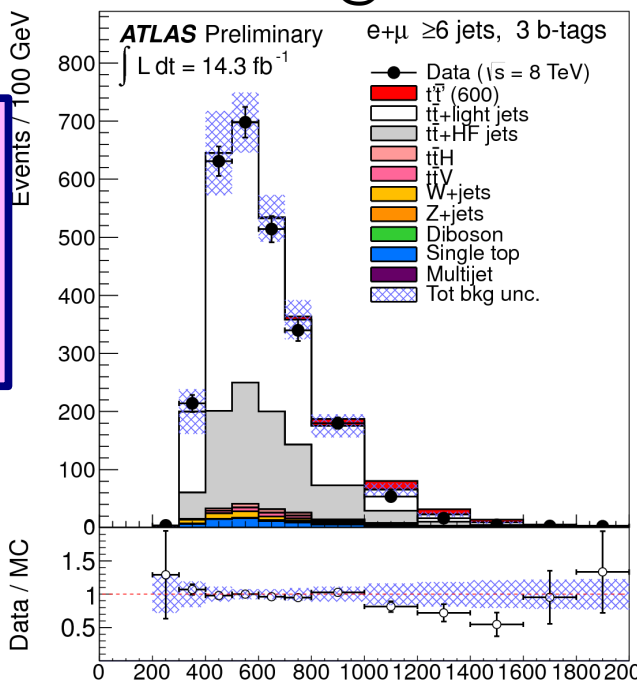


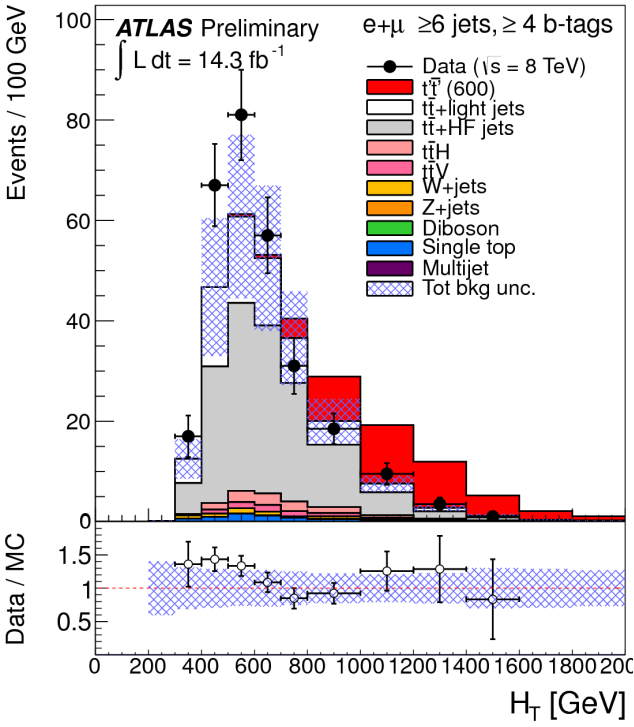


Limits:

- Weak-isospin doublet $m_{t'}$>709 (745) GeV
- Weak-isospin singlet $m_{t'}$>640 (615) GeV

14.3 fb^{-1} @ 8 TeV





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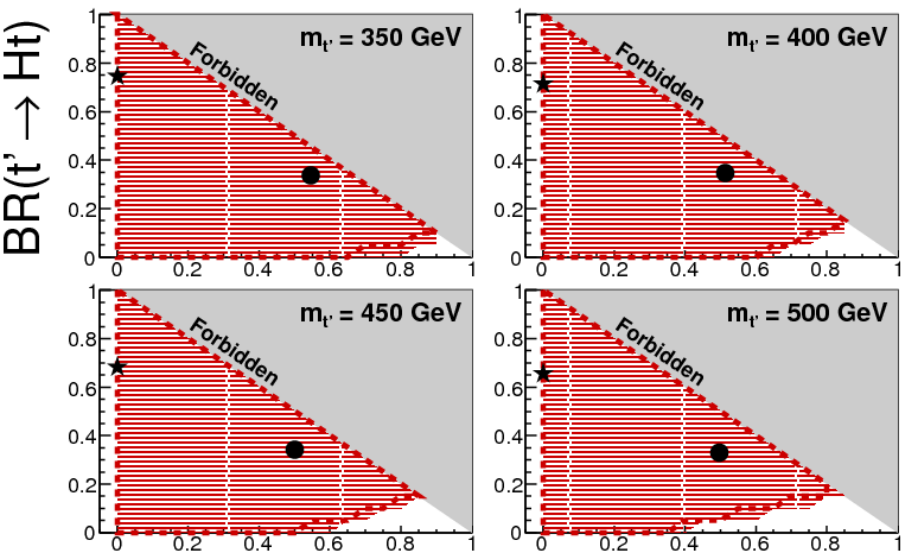
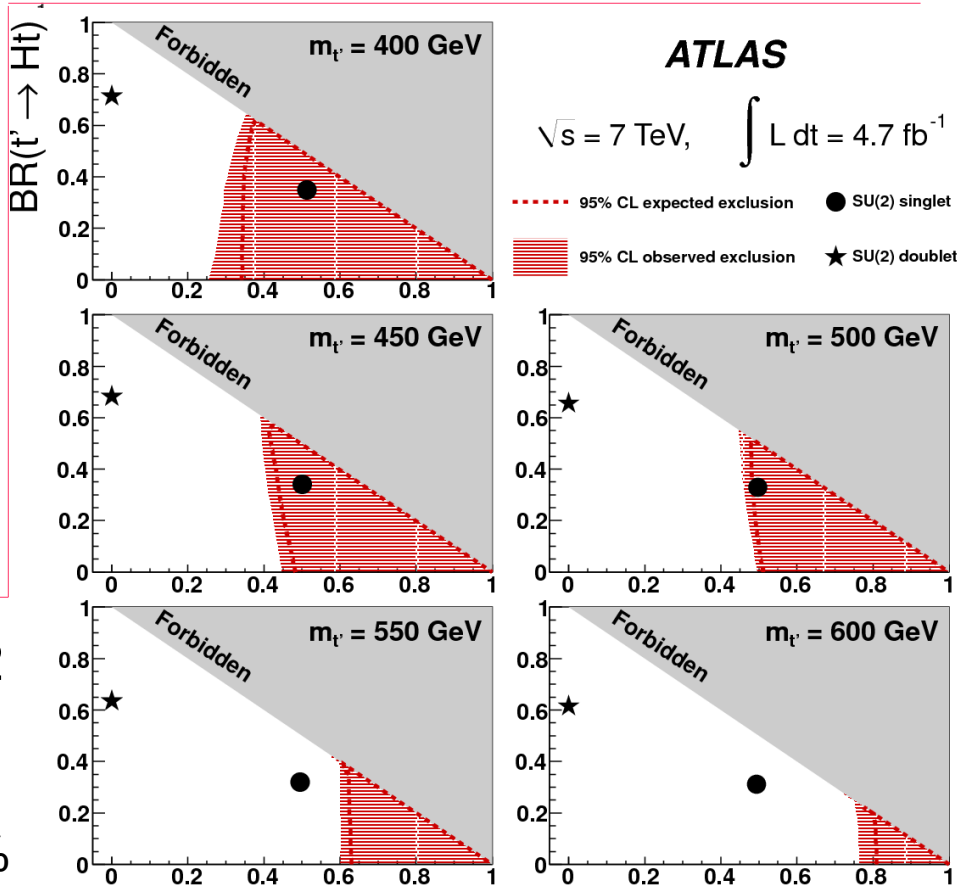
t'→Ht (l+jets)





Phys. Lett. B 718 (2013)1284-1302

t'→Wb (l+jets)

4.7 fb^{-1} @ 7 TeV

With BR(t'→Wb)=100%

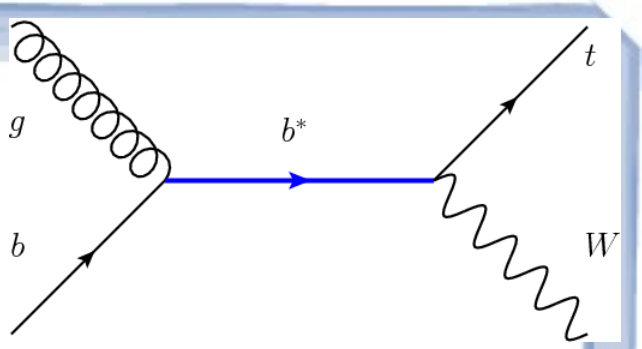
m(t')<656 (638) GeV @ 95% C.L.

Derive additional exclusion limits by reweighting events according to different BR

ATLAS arXiv:1301.1583
Phys. Lett. B 721 (2013) 171-189

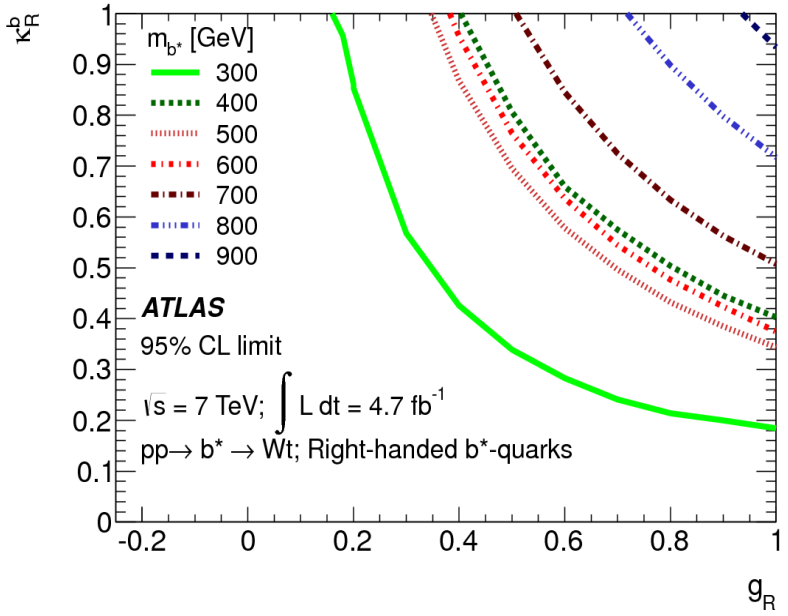
4.7 fb^{-1} @ 7 TeV

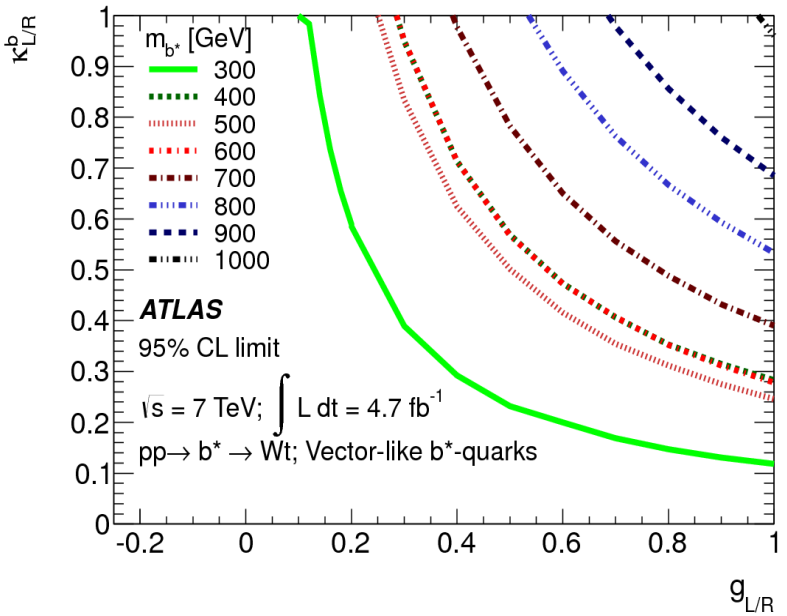
Single bottom-like quark



- Production x-sec and BR($b^* \rightarrow tW$) depending on couplings and b^* mass
  - Chromomagnetic coupling $k^b_{L,R}$
  - Weak coupling strengths $g_{L,R}$
  - Lepton+jets and dilepton channels
- Combined fit to reconstructed b* mass and H_T
- Main backgrounds W+jets estimated from data

Model	Limit Obs (exp)
$k^b_L=g_L=1$	870 (910) GeV
$k^b_R=g_R=1$	920 (950) GeV
$k^b_L=g_L=k^b_R=g_R=1$	1030 (1030) GeV

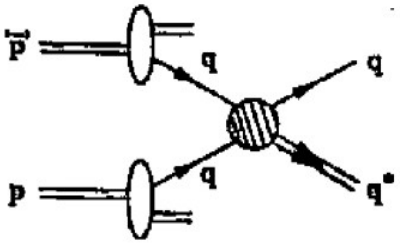


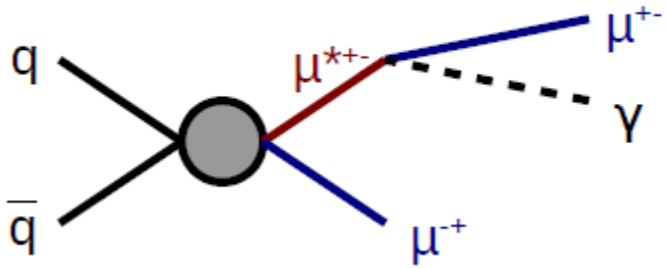


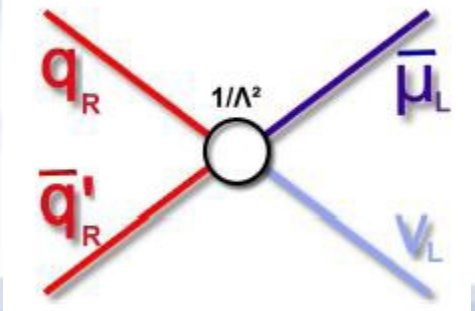
Compositeness

Fermion substructure (Compositeness)

?







Quarks and leptons are probed to be elementary up to scales of 10-15 m or TeV

- Maybe **quarks and leptons substructure**? Constituents = "preons". New strong gauge (metacolor) interaction of scale Lambda Λ is introduced (Pati & Salam, PRD 10 (1974))
- Predicts the **existence of excited quarks q* and leptons l***, produced via contact interactions at colliders
- May explain number of generations, charges, masses of quarks and leptons

How to find compositeness:

- **Excited leptons and quarks** : l, l*, l** , …. q, q*, q**. Sort out by mass (or spin), sharing flavor with corresponding SM particle; direct evidence for fermion substructure in rich spectrum of excited states; Known l,q regarded as ground states
- **4-fermion contact interaction (CI)** below compositeness scale. Deviations in well known spectra

Limits being set on masses of excited ℓ,q and the compositeness scale Λ

e* / mu*→2 leptons+γ

Search for lepton compositeness in pp collisions at 7 TeV in **CMS 2011** data @LHC (luminosity **5.0 fb^{-1}**), excited leptons produced via CI, ll*→ llγ

- Signature: 2 energetic isolated leptons (p_T(e)>35,40GeV, p_T(η)>45,40GeV) and isolated photon (p_T>35GeV), good primary vertex, |η|<2.5
- Background: Drell-Yan $l^+l^-\gamma$ (ISR,FSR), Zjets (jet mis-ident as photon), Wjets (jet mis-ident as e); Z veto applied

95% C.L. excluded cross sections for 0.6 TeV < M(l*) < 2 TeV

e* 1.6 fb – 1.3 fb

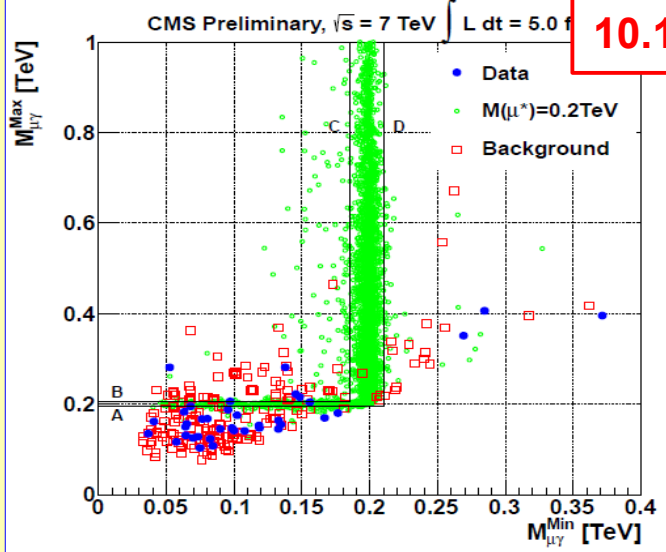
μ* 1.3 fb – 1.1 fb

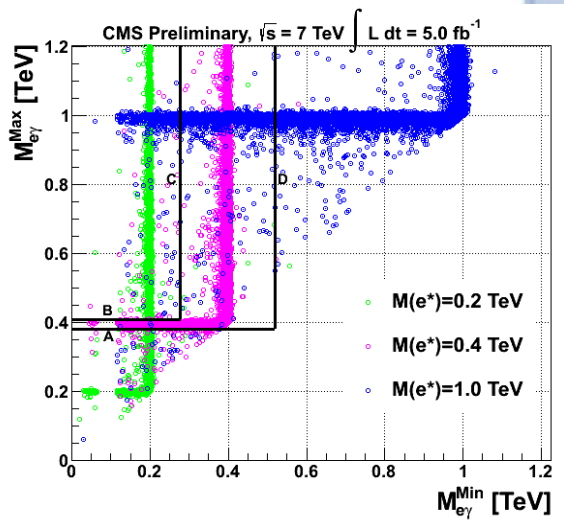
For Λ = M(l*) m_{l*}<1.9 TeV are excluded

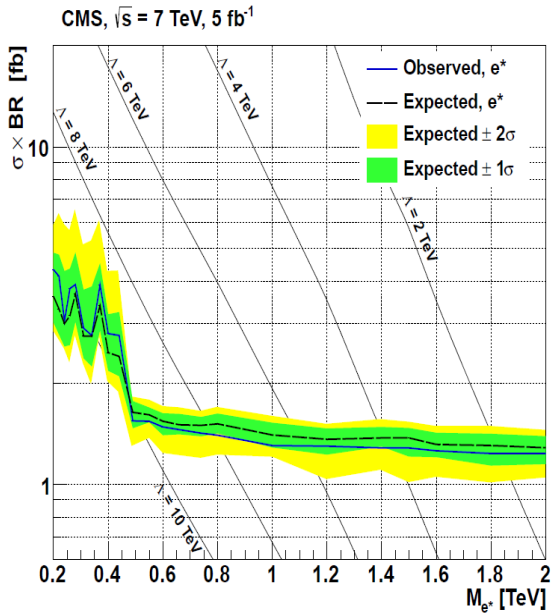
CMS EXO 11-034

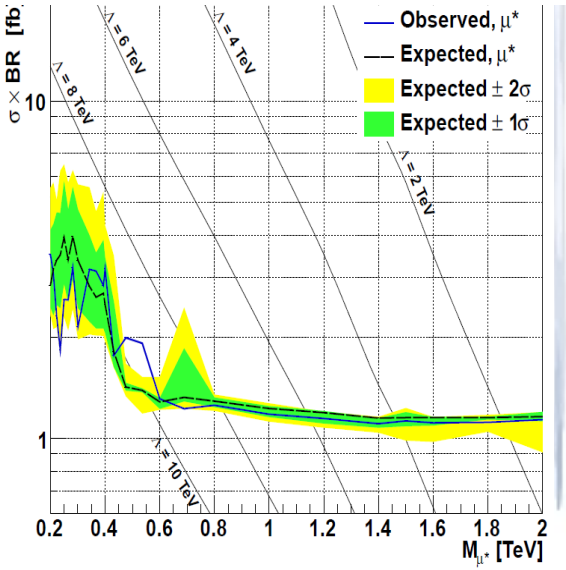
arXiv:1210.2422v1[hep-ex]

10.1016/j.physletb.2013.02.031



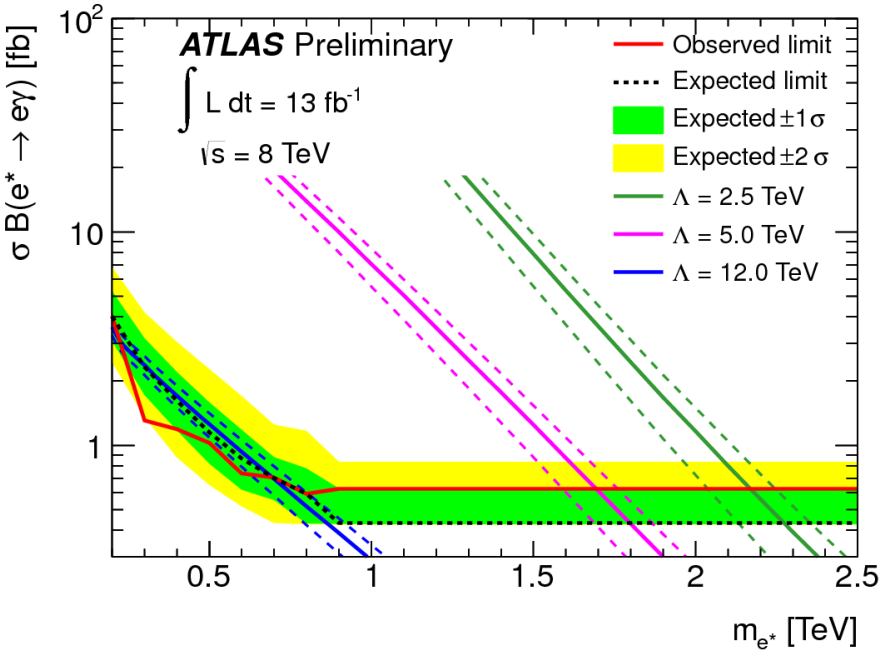


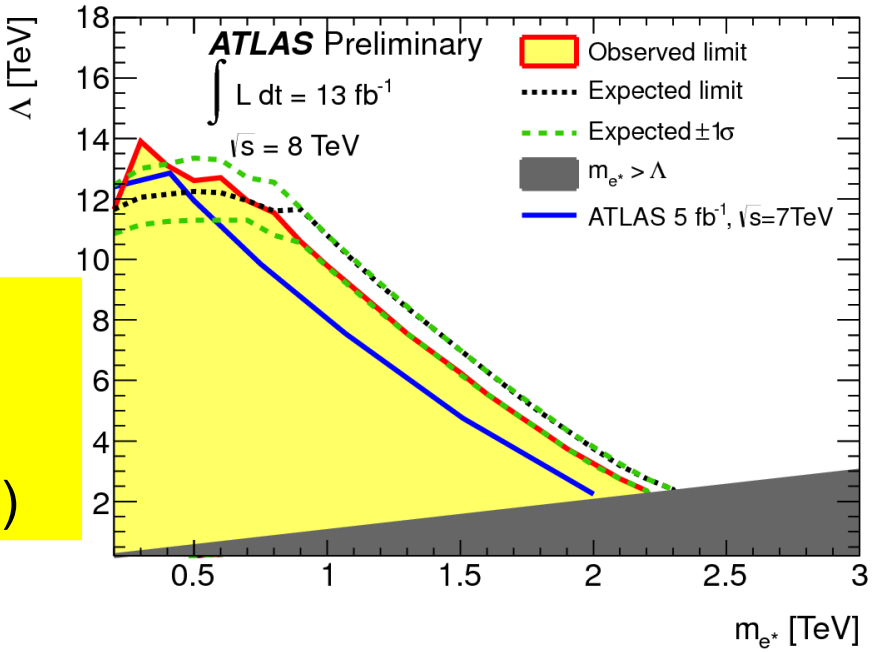




Excited leptons: e* and μ*

- Search for lepton compositeness in single excited lepton production
- Tight isolated photon p_T>30GeV, |η| <2.37, separation R(l,γ)>0.7
  - 75% efficiency
- p_T(e)>40,30 GeV, |η|<2.47 only first isolated, dielectron trigger
  - 85% efficiency
- p_T(μ)>25GeV, |η|<2.5, isolated, single μ trigger, opposite charge
  - 70% efficiency
- Keep highest invariant mass same-flavor lepton pair having m(ll)>110 GeV





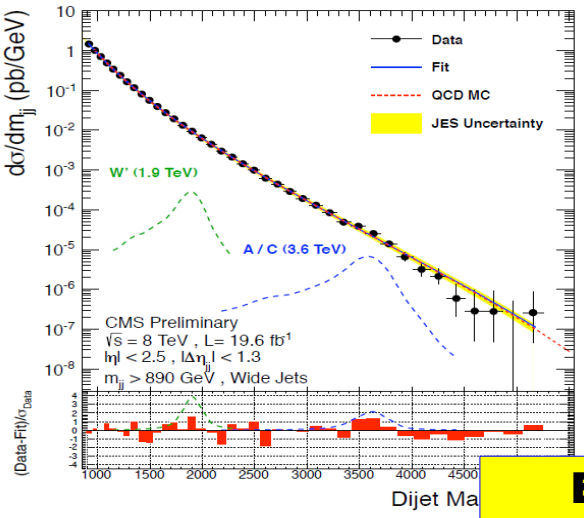
set limits on the compositeness scale Λ
as a function of the excited lepton mass m(ℓ*).

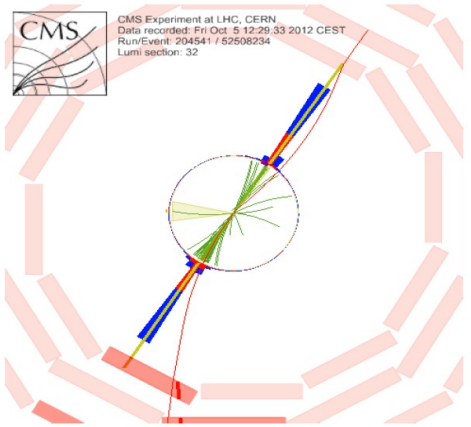
m(ℓ*)< 2.2 TeV excluded at 95% CL for Λ=m(ℓ*)

q*(qg).... → Di Jets

CMS PAS EXO 12-059
Update of arXiv:1212.1910v1[hep-ex] and arXiv:1302.4794v1[hep-ex]

- Many theories addressed with dijet analyses: **excited quarks q* from qg fusion would appear as heavy resonance**
- **Model independent search for narrow resonances in dijets** with res. width < jj mass resol.
- **Bump hunter** systematically looks for "bumps"
- **Search** in pp collisions at **8 TeV in CMS 2012** data @LHC (luminosity **19.6 fb^{-1}**)
- Signature: 2 leading "wide" jets $|\Delta\eta_{jj}|$ <1.3 inside region $|\eta|$<2.5, m_{jj}>890 GeV
- Background: QCD normalized to data

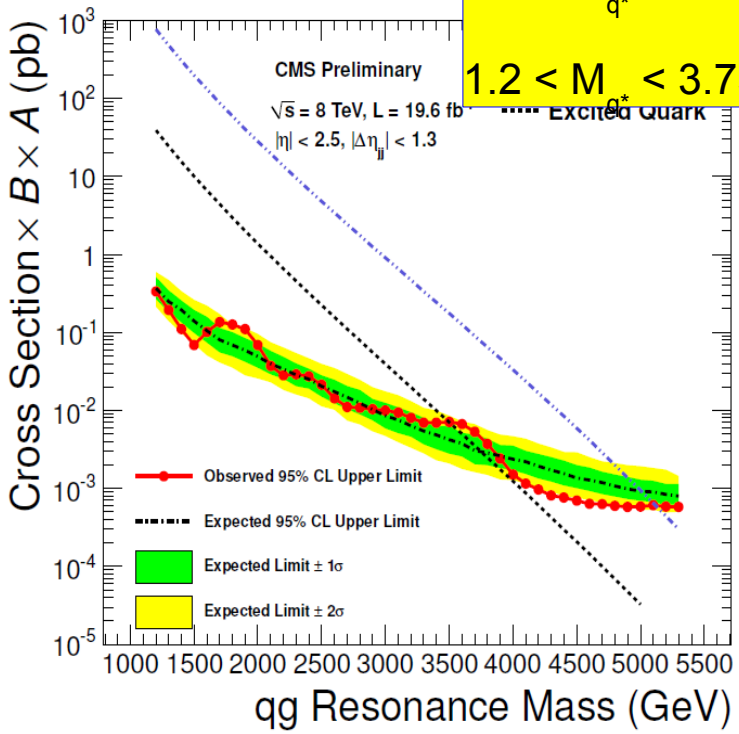




Excluded Mass

$1.2 < M_{q^*} < 3.5$ TeV obs.

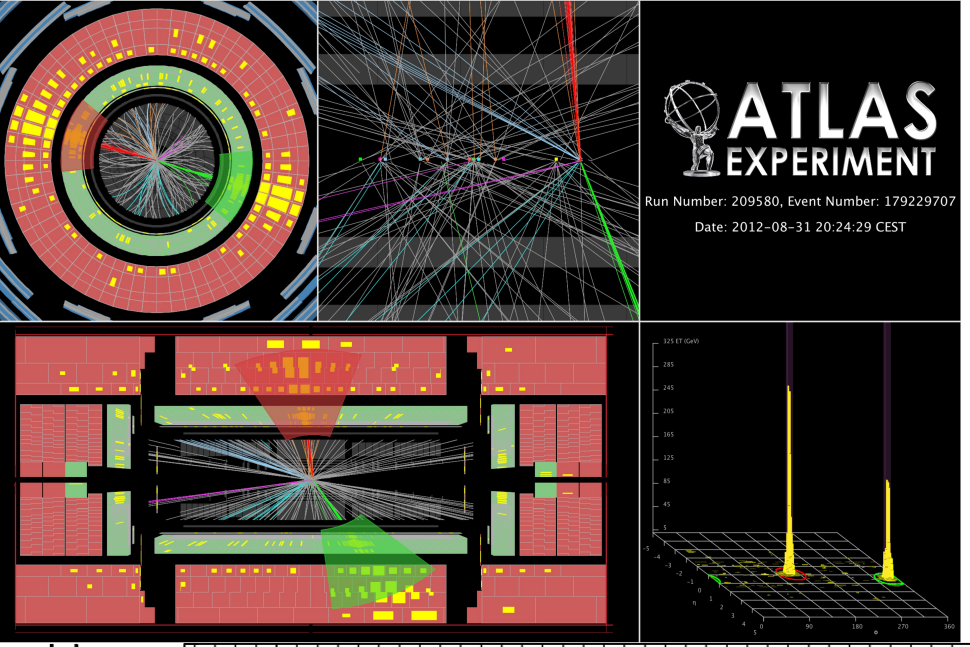
$1.2 < M_{q^*} < 3.75$ TeV exp.

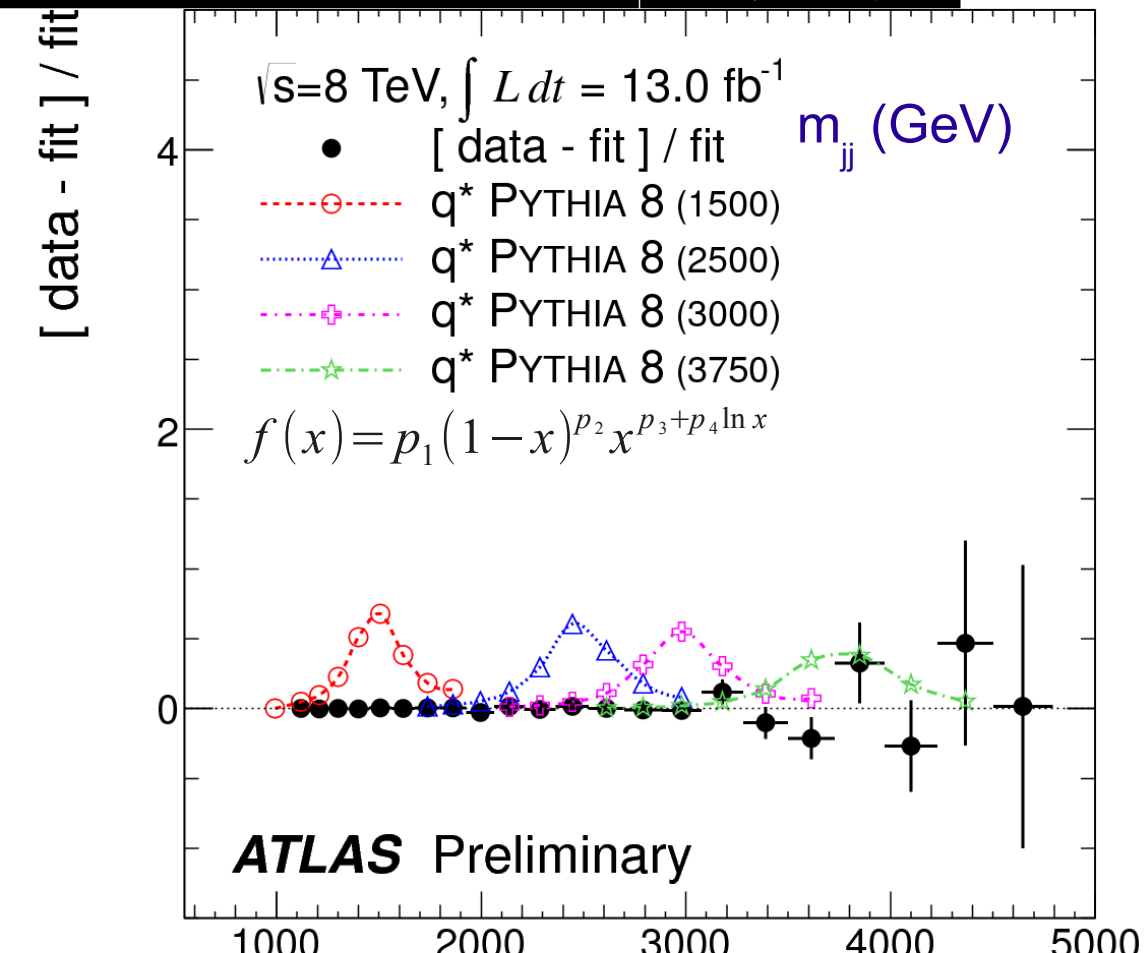


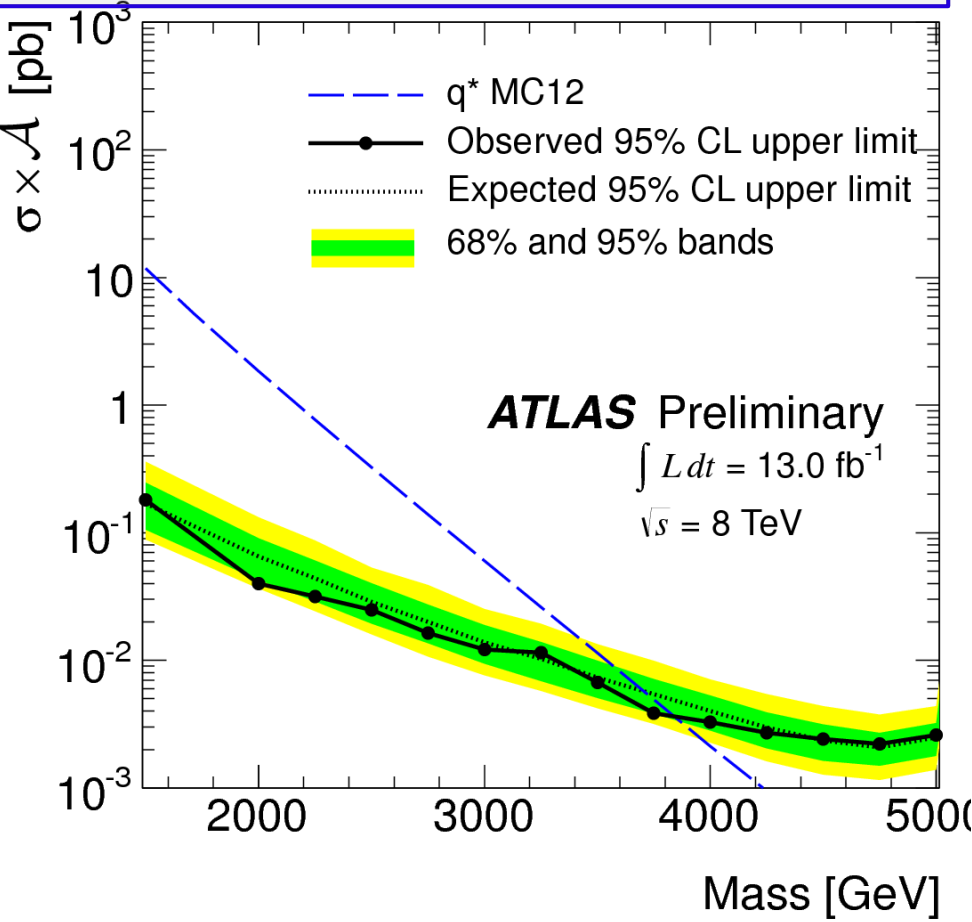
13 fb^{-1} @ 8 TeV

ATLAS-CONF-2012-148

Excited quarks in dijet mass studies

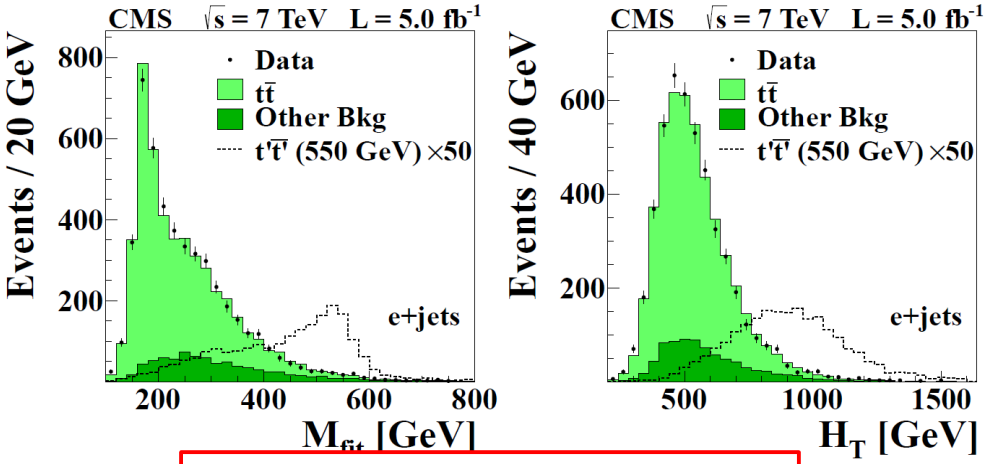




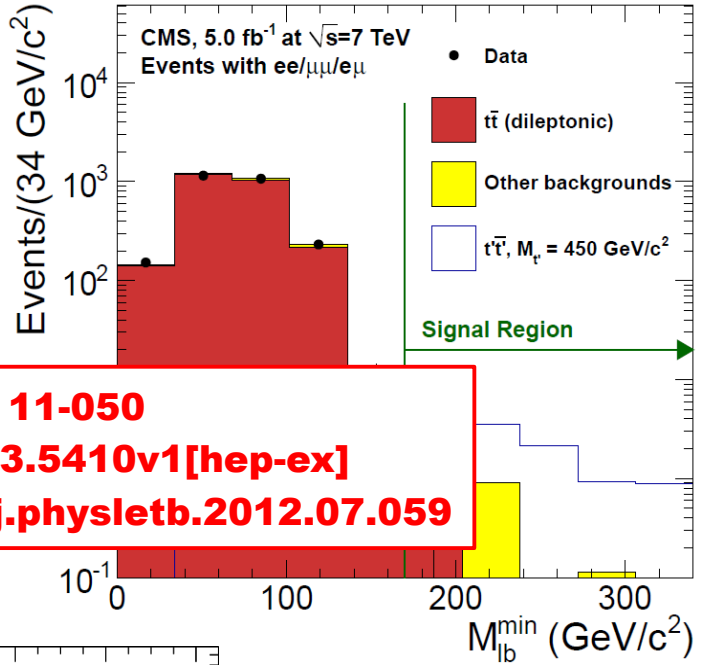


$m_{q^*} > 3.84\ (3.70)$ TeV

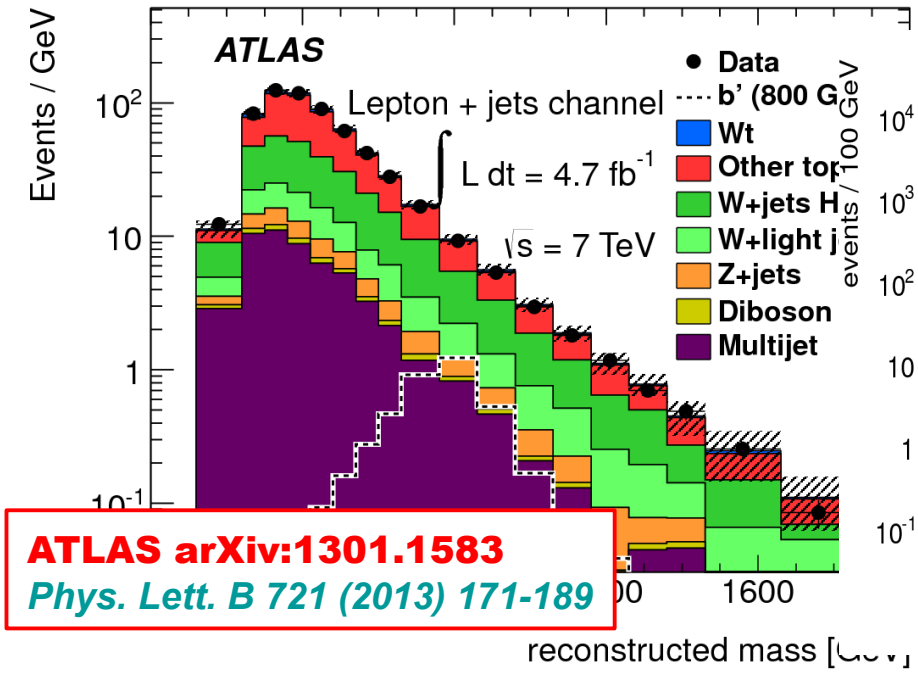
NO EVIDENCE FOR SIGNAL YET FOUND....



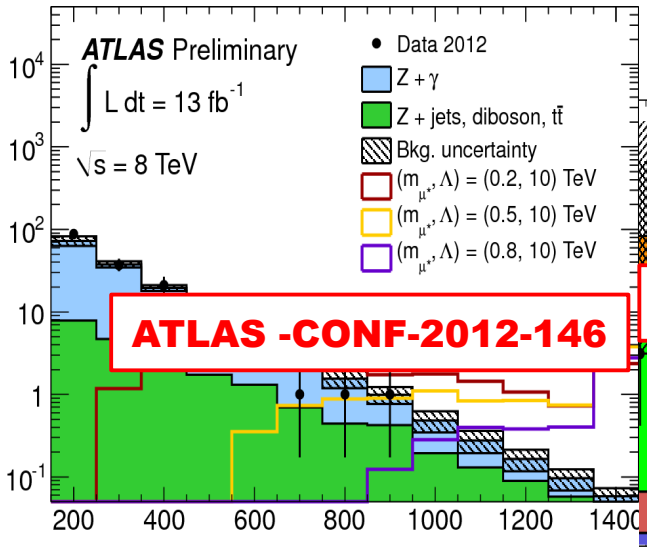
CMS EXO 11-099
arXiv:1209.0471v2[hep-ex]



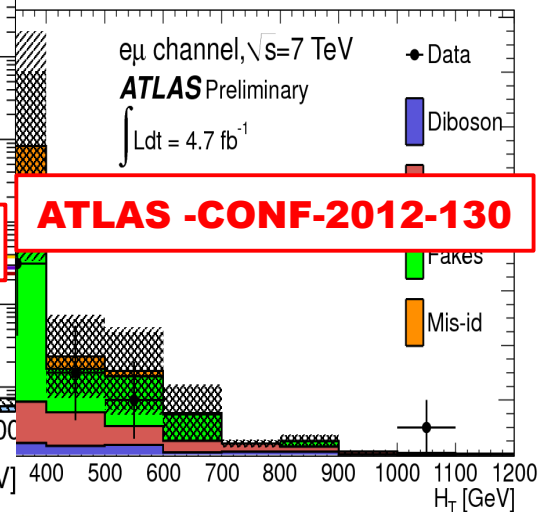
CMS EXO 11-050
arXiv:1203.5410v1[hep-ex]
10.1016/j.physletb.2012.07.059



ATLAS arXiv:1301.1583
Phys. Lett. B 721 (2013) 171-189

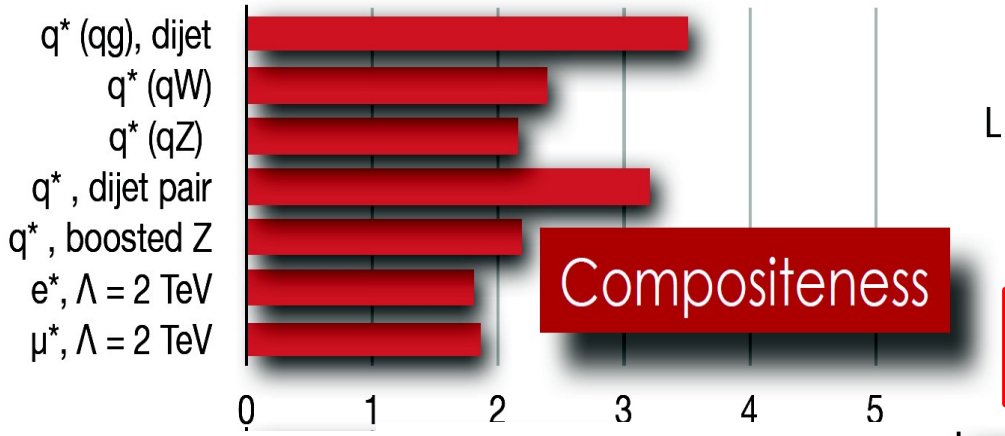


ATLAS -CONF-2012-146

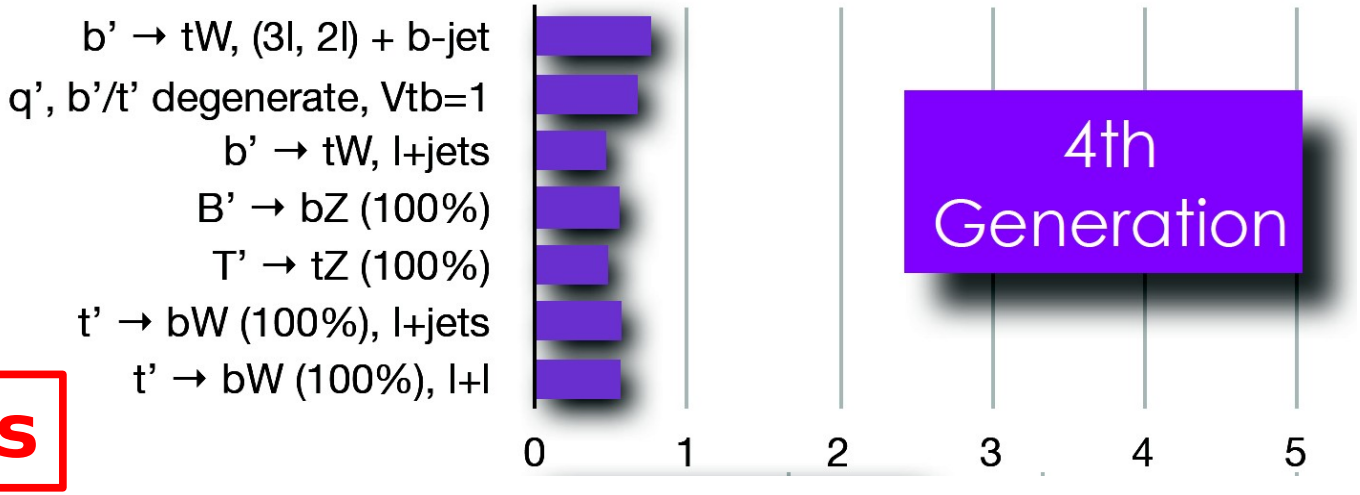


ATLAS -CONF-2012-130

Conclusions



CMS limits (TeV)



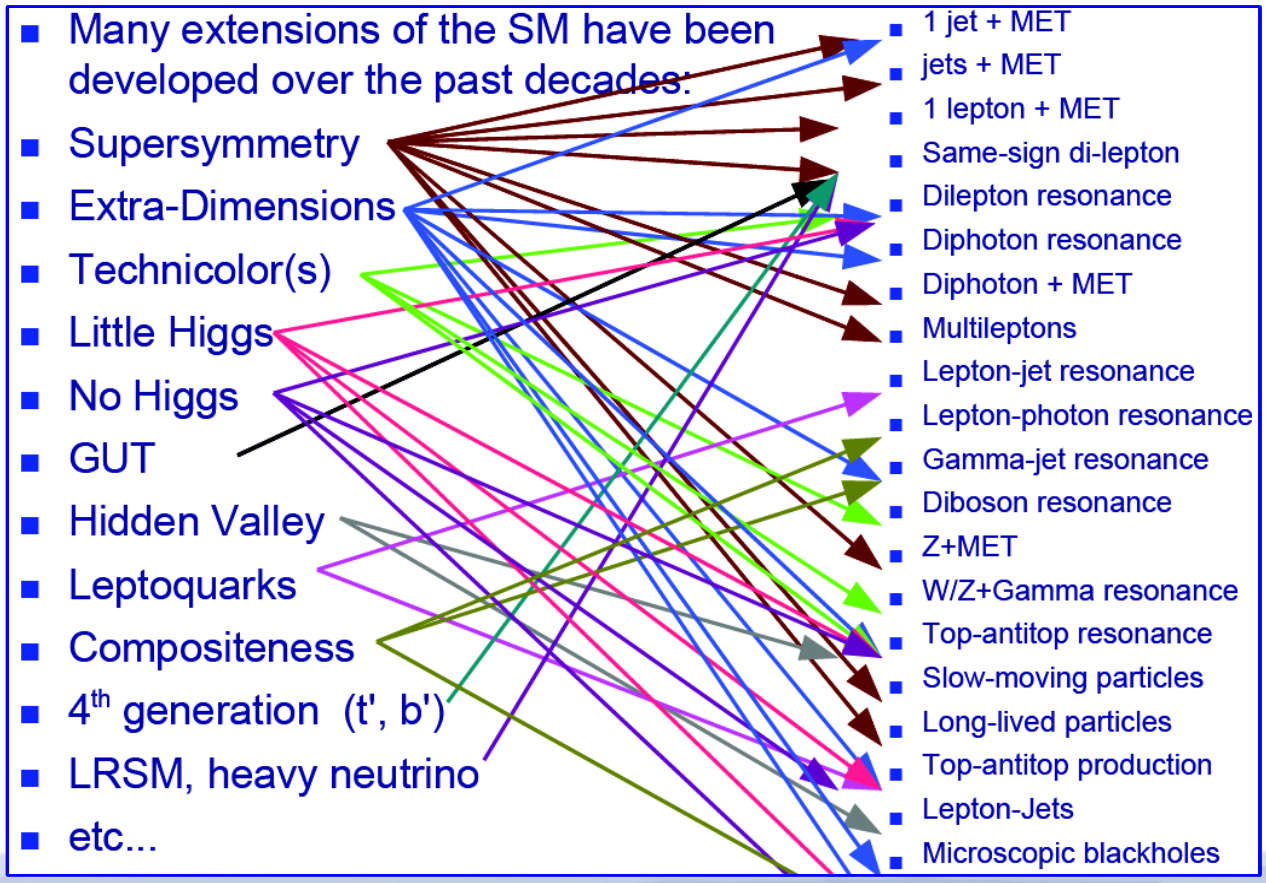
ATLAS limits

Discussion: topic vs signature

1. **Topic-based versus signature based analysis**: many models and large parameters space within each model, wouldn't be better to perform model-independent searches in particular final states?

If and when a signal is found, many models could be probed...

Partially done in ATLAS-CONF-2012-130 for 4th generation and **CMS PAS EXO 12-059** for di-jets mass spectrum.... coulb be extended further?



Discussion: more and next

1. **Analysis update with full datasets 2012:** what is foreseen?
   - **Increase in luminosity is not a game changer... e.g. increase of 35 times in data from 2010 to Summer 2011 improved exclusion limits sometime less than 20%. (better for low-stat channels)**
   - **combine different measures and cover more parameters space**
   - **single produced heavy quarks model could be probed? (but low-thresholds triggers must be in place)**
2. **Run II:**
   - **Could probe 1-2 TeV resonances?**
   - **Pile-up effects on jets, etc?**
   - **Trigger: how single and di-leptons triggers will be updated** (new trigger tables needs? Thresholds? Multi-objects triggers?) … **Trigger upgrade will allow a better coverage, acceptance and pile-up management, with increasing analysis efficiency**.

CMS References

*CMS-PAS-B2G-12-012 ***Search for T5/3 top partners in same-sign dilepton final state*** http://cds.cern.ch/record/1524087 PAS PUB | Notes: AN-2012/435 | CDS Record: 1528573 (2012 Moriond2013)

*CMS-PAS-B2G-12-003 ***Search for a heavy partner of the top quark with charge 5/3*** http://cds.cern.ch/record/1478430 PAS PUB | Rel. to Analysis: EXO-11-085 | Notes: AN-2011/419 | CDS Record: 1478430 (2011)

*B2G-12-004 ***Search for b' pair production in the lepton + jets channel*** ACCEPT Journal: JHEP | b' -> tW with one lepton only | Rel. to Analysis: EXO-11-086 | Notes: AN-2011/454 | CERN preprint: CERN-PH-EP-2012-309 (2011 ICHEP 2012) arXiv:1210.7471 [hep-ex] JHEP 01 (2013) 154

*CMS-PAS-EXO-11-005 ***Search for a Heavy Top-like Quark Pairs at CMS in pp Collisions*** http://cds.cern.ch/record/1367130 ACCEPT Journal: PRL | T'/t' search | Notes: AN-2011/187, AN-2011/050 | CDS Record: 1367130 | CERN preprint: CERN-PH-EP-2011-139 (2011 EPS2011)DOI:10.1103/PhysRevLett.107.271802 arXiv:1109.4985 [hep-ex]

*CMS-EXO-11-099 ***Search for pair produced fourth-generation up-type quarks in pp collisions at ps = 7 TeV with a lepton in the final state*** arXiv:1209.0471v2 [hep-ex] Phys. Lett. B 718 (2012) 307

*CMS-EXO-11-098 ***Combined search for the quarks of a sequential fourth generation*** arXiv:1209.1062v2 [hep-ex] Phys. Rev. D 86 (2012) 112003

*CMS-EXO-11-036 ***Search for heavy bottom-like quarks in 4.9 fb-1 of pp collisions at ps = 7 TeV*** arXiv:1204.1088v2 [hep-ex] JHEP 05 (2012) 123

*CMS-EXO-11-015 ***Search for Resonances in the Dijet Mass Spectrum from 7 TeV pp Collisions at CMS*** arXiv:1107.4771v1 [hep-ex] Phys. Lett. B 704 (2011) 123

*EXO-11-017 ***Search for New Physics in the Dijet Angular Distribution*** PUB Journal:JHEP | Chi Analysis | Notes: AN-2011/320 | CERN preprint: CERN-PH-EP-2012-044 EXO-11-017 (2011 LP2011) arXiv:1202.5535 10.1007/JHEP05(2012)055

*CMS-PAS-EXO-11-034 ***Search for Long-Lived Particles using Displaced Photons in pp Collisions at sqrt(s) = 7 \TeV*** http://cds.cern.ch/record/1460838 PUB Journal: PLB | mu* + e* | Notes: AN-2012/013 | CDS Record: 1460838 (2011 ICHEP 2012) arXiv:1210.2422 10.1016/j.physletb.2013.02.031

*CMS-PAS-EXO-11-050 ***Search for a Heavy Top-like Quark in the Dilepton Final State in pp Collisions at 7~TeV*** http://cds.cern.ch/record/1376672 PUB Journal: PLB | t' (dilepton) | Notes: AN-2011/283, AN-2011/509 | CDS Record: 1376672 (2011 Moriond2012) arXiv:1203.5410 10.1016/j.physletb.2012.07.059

*CMS-PAS-EXO-11-095 ***Search for qW/qZ/WW/WZ/ZZ-Resonances in the W/Z-tagged Dijet Mass Spectrum from 7 TeV pp Collisions at CMS*** http://cds.cern.ch/record/1458050 SUB Journal: PLB | boosted WW, WZ, ZZ, Wjet and Zjet | Notes: AN-2011/524 | CDS Record: 1458050 (2011 Moriond2012) arXiv:1212.1910 submitted to PLB

*CMS-PAS-EXO-12-016 ***Search for Narrow Resonances using the Dijet Mass Spectrum in pp Collisions at sqrt s of 8 TeV*** http://cds.cern.ch/record/1462265 SUB Journal: PRL | dijet HPA ICHEP 2012 | Notes: AN-2012/229 | CDS Record: 1462265 | CERN preprint: CERN-PH-EP-2013-015 (2011 ICHEP 2012) submitted to PR arXiv:1302.4794

*CMS-PAS-EXO-12-059 ***Search for Narrow Resonances using the Dijet Mass Spectrum with 19.6fb-1 of pp Collisions at sqrts=8 TeV*** http://cds.cern.ch/record/1519066 PAS PUB Dijet mass 2012 | Notes: AN-2012/455 | CDS Record: 1519066 (2012 Moriond2013)

ATLAS References

Search for exotic same-sign dilepton signatures (b' quark, T_{5/3} and four top quarks production) in 4.7/fb of pp collisions at sqrt{s}=7 TeV with the ATLAS detector - ATLAS-CONF-2012-130

ATLAS Collaboration, Search for single -quark production with the ATLAS detector at, Physics Letters B, Volume 721, Issues 4–5, 25 April 2013, Pages 171-189, ISSN 0370-2693, 10.1016/j.physletb.2013.03.016.

Search for heavy top-like quarks decaying to a Higgs boson and a top quark in the lepton plus jets final state in pp collisions at s√=8 TeV with the ATLAS detector - ATLAS-CONF-2013-018

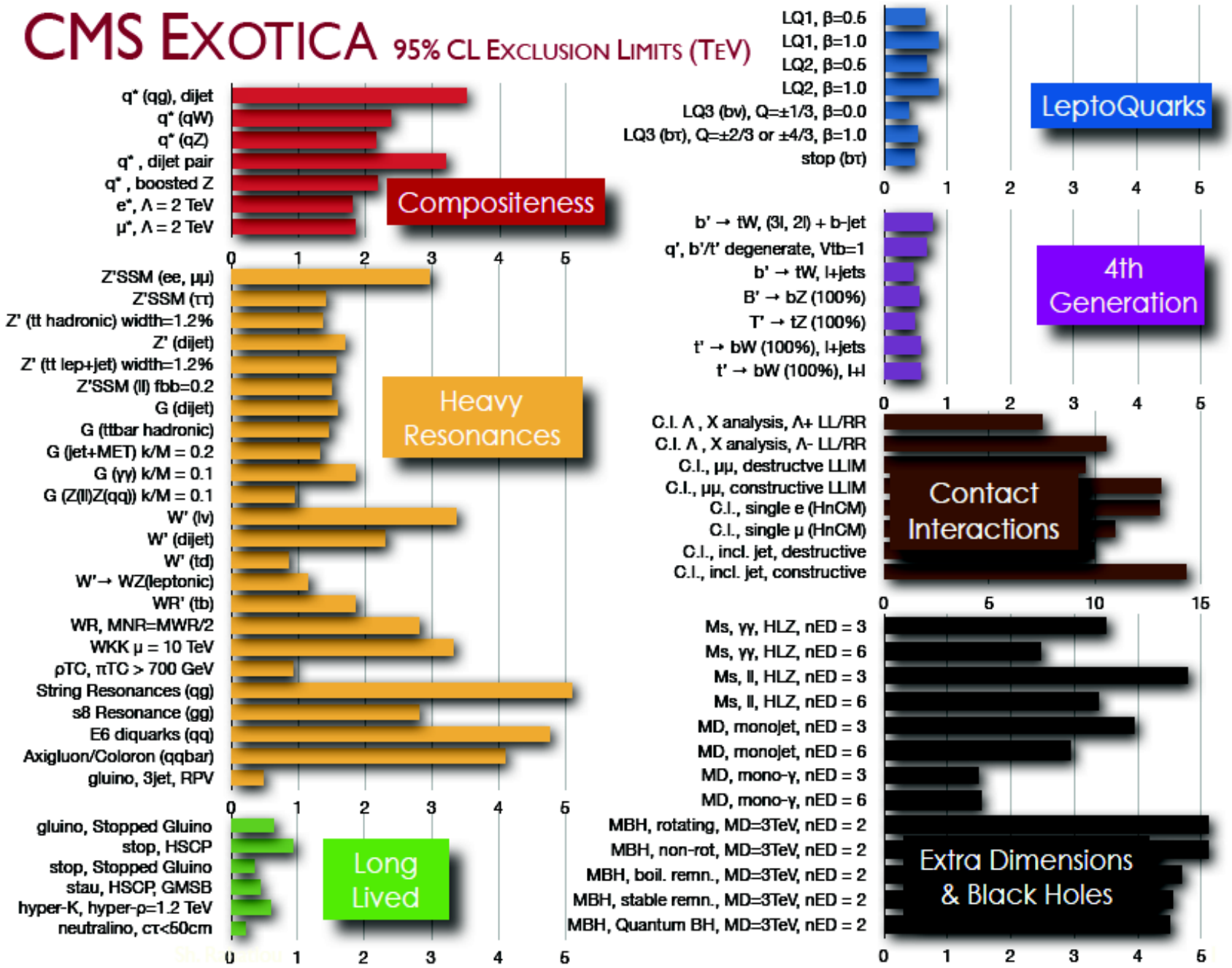
ATLAS Collaboration, Search for pair production of heavy top-like quarks decaying to a high- W boson and a b quark in the lepton plus jets final state at with the ATLAS detector, Physics Letters B, Volume 718, Issues 4–5, 29 January 2013, Pages 1284-1302, ISSN 0370-2693, 10.1016/j.physletb.2012.11.071.

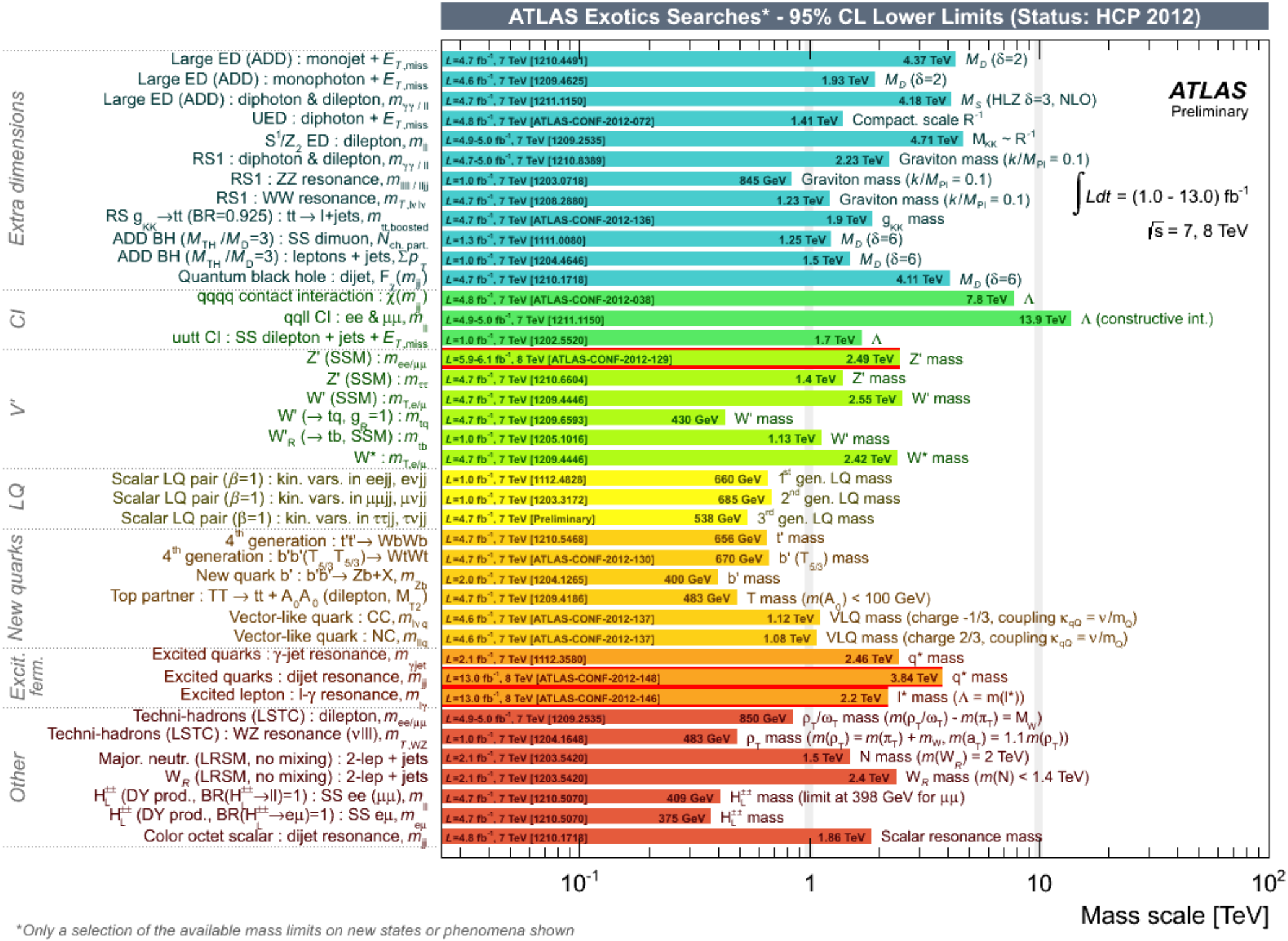
Search for New Phenomena in the Dijet Mass Distribution updated using 13.0 fb^{-1} of pp Collisions at sqrt{s}=8 TeV collected by the ATLAS Detector - ATLAS-CONF-2012-148

ATLAS search for new phenomena in dijet mass and angular distributions using pp collisions at \sqrt{s}=7 TeV, Journal of High Energy Physics, 10.1007/JHEP01(2013)029

ATLAS Collaboration, Search for Pair Production of a New b′ Quark that Decays into a Z Boson and a Bottom Quark with the ATLAS Detector Phys. Rev. Lett. 109, 071801 (2012)

Backup


CMS EXOTICA 95% CL EXCLUSION LIMITS (TEV)
q* (qg), dijet
q* (qW)
q* (qZ)
q* , dijet pair
q* , boosted Z
e*, Λ = 2 TeV
μ*, Λ = 2 TeV
Compositeness
Z'SSM (ee, μμ)
Z'SSM (ττ)
Z' (tt hadronic) width=1.2%
Z' (dijet)
Z' (tt lep+jet) width=1.2%
Z'SSM (ll) fbb=0.2
G (dijet)
G (ttbar hadronic)
G (jet+MET) k/M = 0.2
G (γγ) k/M = 0.1
G (Z(ll)Z(qq)) k/M = 0.1
W' (lν)
W' (dijet)
W' (td)
W'→ WZ(leptonic)
WR' (tb)
WR, MNR=MWR/2
WKK μ = 10 TeV
ρTC, πTC > 700 GeV
String Resonances (qg)
s8 Resonance (gg)
E6 diquarks (qq)
Axigluon/Coloron (qqbar)
gluino, 3jet, RPV
Heavy Resonances
gluino, Stopped Gluino
stop, HSCP
stop, Stopped Gluino
stau, HSCP, GMSB
hyper-K, hyper-ρ=1.2 TeV
neutralino, cτ<50cm
Long Lived
LQ1, β=0.5
LQ1, β=1.0
LQ2, β=0.5
LQ2, β=1.0
LQ3 (bν), Q=±1/3, β=0.0
LQ3 (bτ), Q=±2/3 or ±4/3, β=1.0
stop (bτ)
LeptoQuarks
b' → tW, (3l, 2l) + b-jet
q', b'/t' degenerate, Vtb=1
b' → tW, l+jets
B' → bZ (100%)
T' → tZ (100%)
t' → bW (100%), l+jets
t' → bW (100%), l+l
4th Generation
C.I. Λ , X analysis, Λ+ LL/RR
C.I. Λ , X analysis, Λ- LL/RR
C.I., μμ, destructve LLIM
C.I., μμ, constructive LLIM
C.I., single e (HnCM)
C.I., single μ (HnCM)
C.I., incl. jet, destructive
C.I., incl. jet, constructive
Contact Interactions
Ms, γγ, HLZ, nED = 3
Ms, γγ, HLZ, nED = 6
Ms, ll, HLZ, nED = 3
Ms, ll, HLZ, nED = 6
MD, monojet, nED = 3
MD, monojet, nED = 6
MD, mono-γ, nED = 3
MD, mono-γ, nED = 6
MBH, rotating, MD=3TeV, nED = 2
MBH, non-rot, MD=3TeV, nED = 2
MBH, boil. remn., MD=3TeV, nED = 2
MBH, stable remn., MD=3TeV, nED = 2
MBH, Quantum BH, MD=3TeV, nED = 2
Extra Dimensions & Black Holes

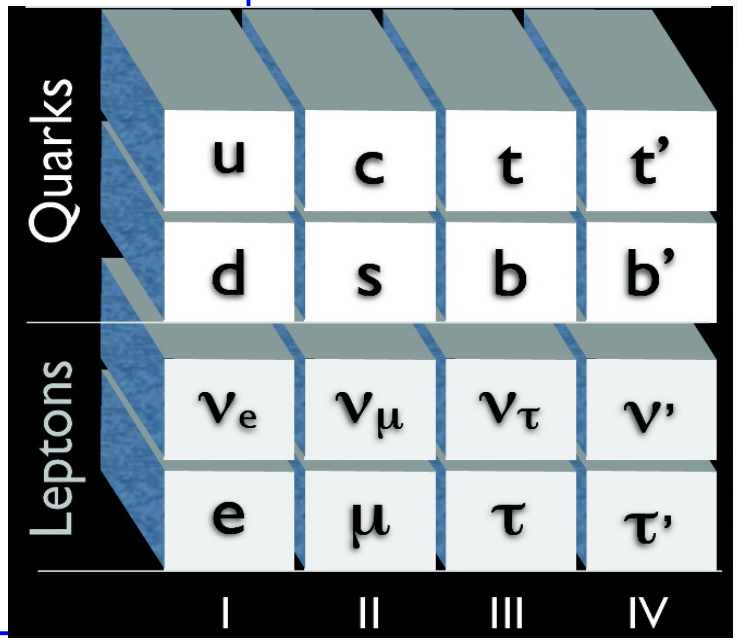

ATLAS Exotics Searches* - 95% CL Lower Limits (Status: HCP 2012)
ATLAS
Preliminary
∫Ldt = (1.0 - 13.0) fb-1
√s = 7, 8 TeV
Extra dimensions
Large ED (ADD) : monojet + E_T,miss
Large ED (ADD) : monophoton + E_T,miss
Large ED (ADD) : diphoton & dilepton, m_γγ / ll
UED : diphoton + E_T,miss
S1/Z2 ED : dilepton, m_ll
RS1 : diphoton & dilepton, m_γγ / ll
RS1 : ZZ resonance, m_llll / lljj
RS1 : WW resonance, m_T,lν lν
RS g_KK→tt (BR=0.925) : tt → l+jets, m_tt,boosted
ADD BH (M_TH /M_D=3) : SS dimuon, N_ch. part.
ADD BH (M_TH /M_D=3) : leptons + jets, Σp_T
Quantum black hole : dijet, F_χ(m_jj)
CI
qqqq contact interaction : χ(m_jj)
qqll CI : ee & μμ, m_ll
uutt CI : SS dilepton + jets + E_T,miss
V'
Z' (SSM) : m_ee/μμ
Z' (SSM) : m_ττ
W' (SSM) : m_T,e/μ
W' (→ tq, g_R=1) : m_tq
W'_R (→ tb, SSM) : m_tb
W* : m_T,e/μ
LQ
Scalar LQ pair (β=1) : kin. vars. in eejj, evjj
Scalar LQ pair (β=1) : kin. vars. in μμjj, μvjj
Scalar LQ pair (β=1) : kin. vars. in ττjj, τvjj
New quarks
4th generation : t't'→ WbWb
4th generation : b'b'(T5/3 T5/3)→ WtWt
New quark b' : b'b'→ Zb+X, m_Zb
Top partner : TT → tt + A0A0 (dilepton, MT2)
Vector-like quark : CC, m_lν q
Vector-like quark : NC, m_llq
Excit. ferm.
Excited quarks : γ-jet resonance, m_γjet
Excited quarks : dijet resonance, m_jj
Excited lepton : l-γ resonance, m_lγ
Other
Techni-hadrons (LSTC) : dilepton, m_ee/μμ
Techni-hadrons (LSTC) : WZ resonance (νlll), m_T,WZ
Major. neutr. (LRSM, no mixing) : 2-lep + jets
W_R (LRSM, no mixing) : 2-lep + jets
H_L±± (DY prod., BR(H_L±±→ll)=1) : SS ee (μμ), m_ll
H_L±± (DY prod., BR(H_L±±→eμ)=1) : SS eμ, m_eμ
Color octet scalar : dijet resonance, m_jj
L=4.7 fb-1, 7 TeV [1210.4491] 4.37 TeV M_D (δ=2)
L=4.6 fb-1, 7 TeV [1209.4625] 1.93 TeV M_D (δ=2)
L=4.7 fb-1, 7 TeV [1211.1150] 4.18 TeV M_S (HLZ δ=3, NLO)
L=4.8 fb-1, 7 TeV [ATLAS-CONF-2012-072] 1.41 TeV Compact. scale R-1
L=4.9-5.0 fb-1, 7 TeV [1209.2535] 4.71 TeV M_KK ~ R-1
L=4.7-5.0 fb-1, 7 TeV [1210.8389] 2.23 TeV Graviton mass (k/M_Pl = 0.1)
L=1.0 fb-1, 7 TeV [1203.0718] 845 GeV Graviton mass (k/M_Pl = 0.1)
L=4.7 fb-1, 7 TeV [1208.2880] 1.23 TeV Graviton mass (k/M_Pl = 0.1)
L=4.7 fb-1, 7 TeV [ATLAS-CONF-2012-136] 1.9 TeV g_KK mass
L=1.3 fb-1, 7 TeV [1111.0080] 1.25 TeV M_D (δ=6)
L=1.0 fb-1, 7 TeV [1204.4646] 1.5 TeV M_D (δ=6)
L=4.7 fb-1, 7 TeV [1210.1718] 4.11 TeV M_D (δ=6)
L=4.8 fb-1, 7 TeV [ATLAS-CONF-2012-038] 7.8 TeV Λ
L=4.9-5.0 fb-1, 7 TeV [1211.1150] 13.9 TeV Λ (constructive int.)
L=1.0 fb-1, 7 TeV [1202.5520] 1.7 TeV Λ
L=5.9-6.1 fb-1, 8 TeV [ATLAS-CONF-2012-129] 2.49 TeV Z' mass
L=4.7 fb-1, 7 TeV [1210.6604] 1.4 TeV Z' mass
L=4.7 fb-1, 7 TeV [1209.4446] 2.55 TeV W' mass
L=4.7 fb-1, 7 TeV [1209.6593] 430 GeV W' mass
L=1.0 fb-1, 7 TeV [1205.1016] 1.13 TeV W' mass
L=4.7 fb-1, 7 TeV [1209.4446] 2.42 TeV W* mass
L=1.0 fb-1, 7 TeV [1112.4828] 660 GeV 1st gen. LQ mass
L=1.0 fb-1, 7 TeV [1203.3172] 685 GeV 2nd gen. LQ mass
L=4.7 fb-1, 7 TeV [Preliminary] 538 GeV 3rd gen. LQ mass
L=4.7 fb-1, 7 TeV [1210.5468] 656 GeV t' mass
L=4.7 fb-1, 7 TeV [ATLAS-CONF-2012-130] 670 GeV b' (T5/3) mass
L=2.0 fb-1, 7 TeV [1204.1265] 400 GeV b' mass
L=4.7 fb-1, 7 TeV [1209.4186] 483 GeV T mass (m(A0) < 100 GeV)
L=4.6 fb-1, 7 TeV [ATLAS-CONF-2012-137] 1.12 TeV VLQ mass (charge -1/3, coupling κqQ = v/mQ)
L=4.6 fb-1, 7 TeV [ATLAS-CONF-2012-137] 1.08 TeV VLQ mass (charge 2/3, coupling κqQ = v/mQ)
L=2.1 fb-1, 7 TeV [1112.3580] 2.46 TeV q* mass
L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-148] 3.84 TeV q* mass
L=13.0 fb-1, 8 TeV [ATLAS-CONF-2012-146] 2.2 TeV l* mass (Λ = m(l*))
L=4.9-5.0 fb-1, 7 TeV [1209.2535] 850 GeV ρT/ωT mass (m(ρT/ωT) - m(πT) = MW)
L=1.0 fb-1, 7 TeV [1204.1648] 483 GeV ρT mass (m(ρT) = m(πT) + mW, m(aT) = 1.1m(ρT))
L=2.1 fb-1, 7 TeV [1203.5420] 1.5 TeV N mass (m(WR) = 2 TeV)
L=2.1 fb-1, 7 TeV [1203.5420] 2.4 TeV WR mass (m(N) < 1.4 TeV)
L=4.7 fb-1, 7 TeV [1210.5070] 409 GeV H_L±± mass (limit at 398 GeV for μμ)
L=4.7 fb-1, 7 TeV [1210.5070] 375 GeV H_L±± mass
L=4.8 fb-1, 7 TeV [1210.1718] 1.86 TeV Scalar resonance mass
10-1
1
10
10^2
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown

4TH GENERATION MODEL

- **It is the simplest and natural extension of Standard Model**
  - ➡ SM does not give #families => not a true modification
  - ➡ It is **consistent with precision electroweak** measurements
  - ➡ **upper bound from QCD** (asymptotic freedom): #families<9
  - ➡ **predicts 4 new heavy fermions with 1TeV > m >100GeV**
  - ➡ Heavy top-like quark can **resolve the naturalness** problem (light Higgs)

- **Predicted heavy partners of the top and bottom quarks:**
  - ➡ not limited to chiral quarks
  - ➡ strongly **pair produced**
  - ➡ with **mass greater than top quark**
  - ➡ **decay promptly**
  - ➡ **mixing III-IV generation**
  - ➡ small **mass splitting preferred**

- **Searches in CMS and ATLAS include:**
  - ✔ Vector-like heavy quarks
  - ✔ Top-like quarks in di-lepton and single-lepton channel
  - ✔ Bottom-like quarks in di-lepton channels
  - ✔ Single-bottom quark
  - ✔ Combined t' and b' search in multi-leptons channels



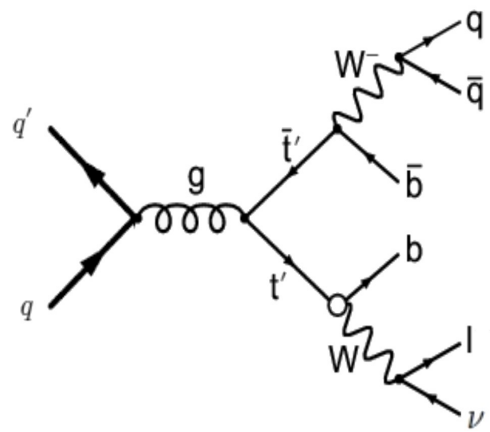
$m_{t'} > 256$ GeV; $m_{b'} > 128$ GeV (CC decay; 199 GeV for 100% NC decay);

$m_{\tau'} > 100.8$ GeV; $m_{\nu'_\tau} > 90.3$ GeV (Dirac coupling; 80.5 GeV for Majorana coupling)

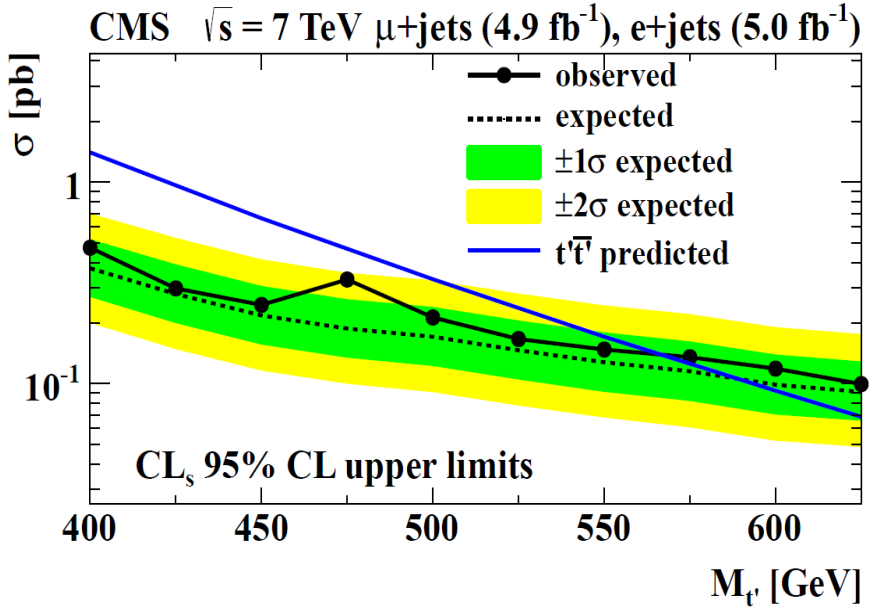
$Q\bar{Q}\rightarrow bW^+\bar{b}W^-\rightarrow$..... 1 Lepton + Jets

Pair-produced forth generation top-like quarks search in pp collisions at 7 TeV in **CMS 2011** data @LHC (luminosity 5.0 fb^{-1})

CMS EXO 11-099
arXiv:1209.0471v2[hep-ex]
Phys. Lett. B 718 (2012) 307



- BR(t'→bW)=100%
- **$Q\bar{Q}\rightarrow bW^+\bar{b}W^-\rightarrow b\ell^+\nu\bar{b}\bar{q}'q$**
- Signature: single isolated lepton p_T>35GeV, MET, at least 4 jets p_T>120,90,50,35GeV
- Use of H_T versus M_{fit} ($M(\bar{b}q'q)$) to test presence of signal



$M_{t'} > 570$ GeV

- Most restrictive yet found
- Raise the lower limit where non perturbative effect become significant!
- Results can be extended to non-chiral heavy quarks decaying to Wb: interpret as limit on σtimes BR(t'→Wb)

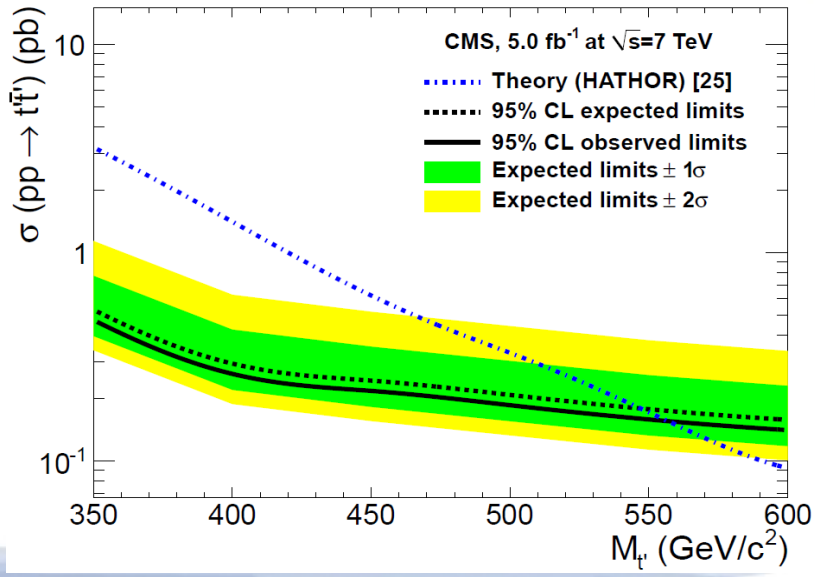
$Q\bar{Q} \rightarrow bW^+\bar{b}W^- \rightarrow$.....2 Leptons + Jets

CMS EXO 11-050
arXiv:1203.5410v1[hep-ex]
10.1016/j.physletb.2012.07.059

- Forth generation **Top-like quark pair search** in pp collisions at 7 TeV in **CMS 2011** data @LHC (luminosity 5.0 fb^{-1})
- $Q\bar{Q} \rightarrow bW^+\bar{b}W^- \rightarrow b\ell^+\nu\bar{b}\ell^-\nu$
- Signature: 2 opposite sign isoletad leptons p_T>20GeV, Z-veto, at least 2 jets p_T>30GeV (2 b-tag), $M^{min}_{b\ell}$>170 GeV
- Background: mis-identification of b jets (mis-tags) and leptons (not prompt)

$M_Q >_{exp}$ 547 GeV

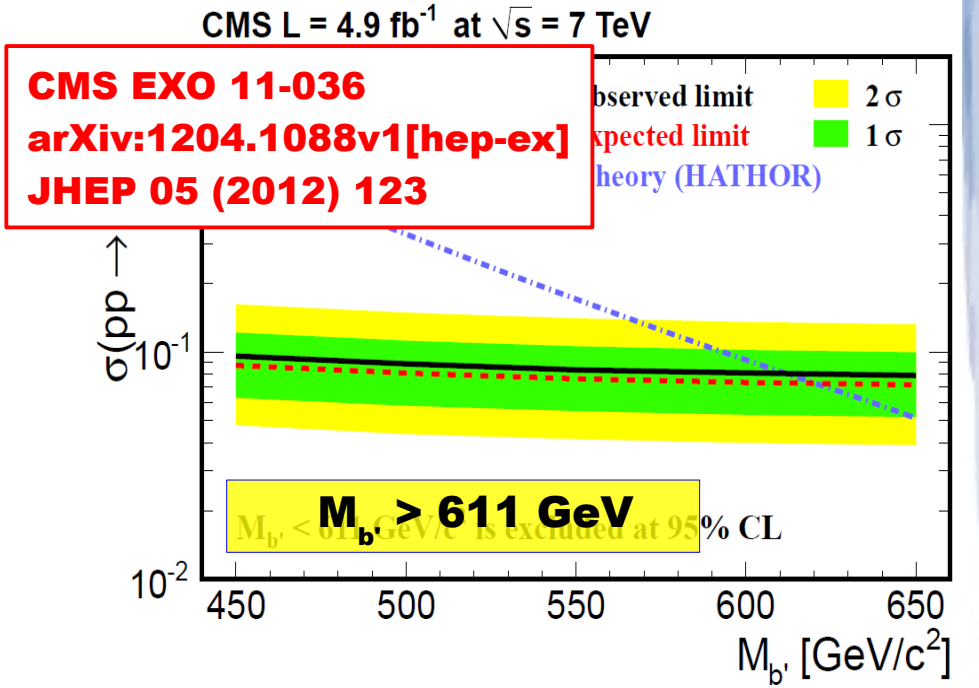
$M_Q >_{obs}$ 557 GeV



$Q\bar{Q} \rightarrow tW^{-}\bar{t}W^{+} \rightarrow$.....2 Leptons + Jets

FIRST SEARCH for PAIR-PRODUCED BOTTOM-LIKE B QUARK

- Forth generation of quarks search in pp collisions at 7 TeV in CMS 2011 data @LHC (luminosity 4.9 fb^{-1})
- Final state: $b'\bar{b}' \rightarrow tW^{-}\bar{t}W^{+} \rightarrow bW^{-}W^{+}\bar{b}W^{-}W^{+}$
- Signature: 2 (3) isolated leptons (2 same-sign, p_T>20GeV), at least 4(2) jets (p_T>25GeV), 1 b-tagged, S_T>500GeV
- Background: single-top, ttW, ttZ
- Z veto rejection



3 Leptons + Jets

Vector-like model

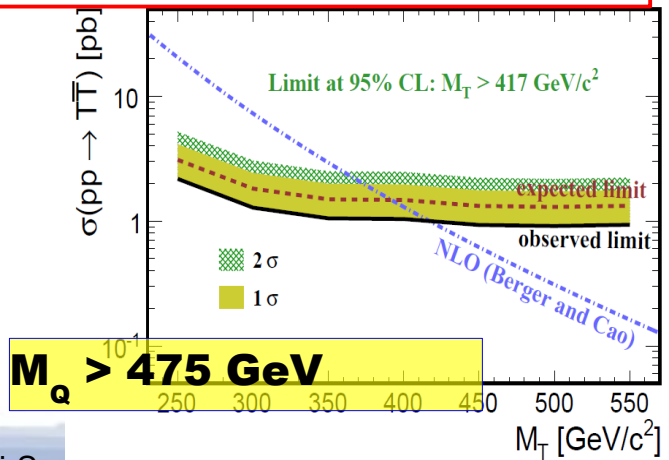
- Non-chiral heavy quarks Q
- Vector-like couplings with bosons
- Stabilize Higgs mass to elecroweak symmetry breaking scale
- Flavour-changing neutral-current processes (Q→tZ and Q→tH)
- Tree-level FCNC couplings results in large branching fractions
- BR(Q→tZ) = 100% if Higgs decay kinematically forbidden

→ relaxed bound on higgs boson mass

→ explain the barion asymmetry of the universe

- Vector-like charge 2/3 quark search signal in pp collisions at 7 TeV in **CMS 2011** data @LHC (luminosity 1.14 fb^{-1})
- Signature: leptonic Z boson decay, at least 3 leptons and 2 jets, R_T (p_T sum exept for two highest- p_T objects)>80 GeV
- Background: events with 3 prompt leptons, and 2 prompt leptons and a fake

CMS EXO 11-005
ArXiv:1109.4985v1[hep-ex]
10.1103/PhysRevLett.107.271802

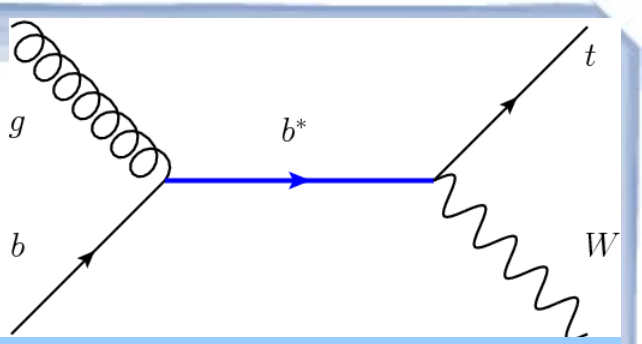


M_Q > 475 GeV

ATLAS arXiv:1301.1583
Phys. Lett. B 721 (2013) 171-189

4.7 fb^{-1} @ 7 TeV

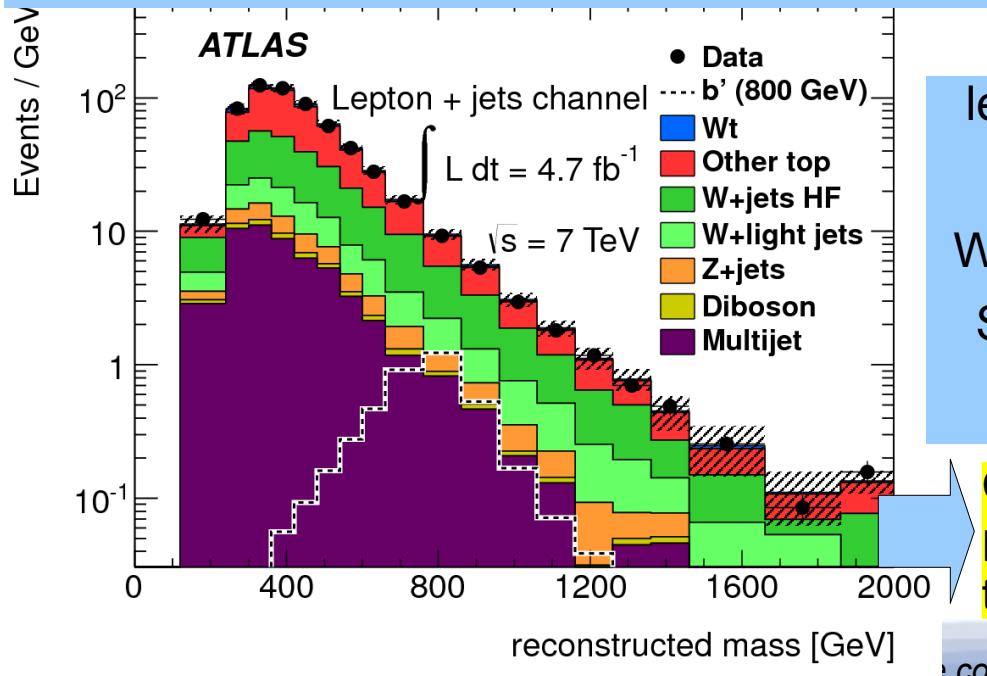
Single bottom-like quark



- Production x-sec and BR($b^* \to tW$) depending on couplings and b^* mass
  - Chromomagnetic coupling $k^b_{L,R}$
  - Weak coupling strengths $g_{L,R}$

Left-handed	$k_L \neq 0, k_R = 0$	$g_L \neq 0, g_R = 0$
Right-handed	$k_L = 0, k_R \neq 0$	$g_L = 0, g_R \neq 0$
Vector-like	$k_L = k_R \neq 0$	$g_L = g_R \neq 0$

Signature (iso)	ET miss	jets	b-tag	Other cuts
e (E_T>25 GeV)	>30 GeV	3 (p_T>25 GeV)	1	m_T^W>30GeV
μ (p_T>25 GeV)	>25 GeV	3 (p_T>25 GeV)	1	$m_T^W + E_T^{miss}$>60GeV
ee, eμ, μμ OS	>50 GeV	1 (p_T>30 GeV)	0	Z-veto



Backgrounds

lepton+jets	
$t\bar{t}$	41%
W+jets (HF)	37%(28%)
Single top	9%
multijet	9%

Dilepton	
$t\bar{t}$	63%
SM Wt	13%
Diboson	12%
fakes	4%

Combine with H_T (= scalar p_T sum of leptons, jets, and ETmiss) distribution from dilepton channel for extracting the limits

ATLAS arXiv:1301.1583
Phys. Lett. B 721 (2013) 171-189

4.7 fb^{-1} @ 7 TeV

Single bottom-like quark

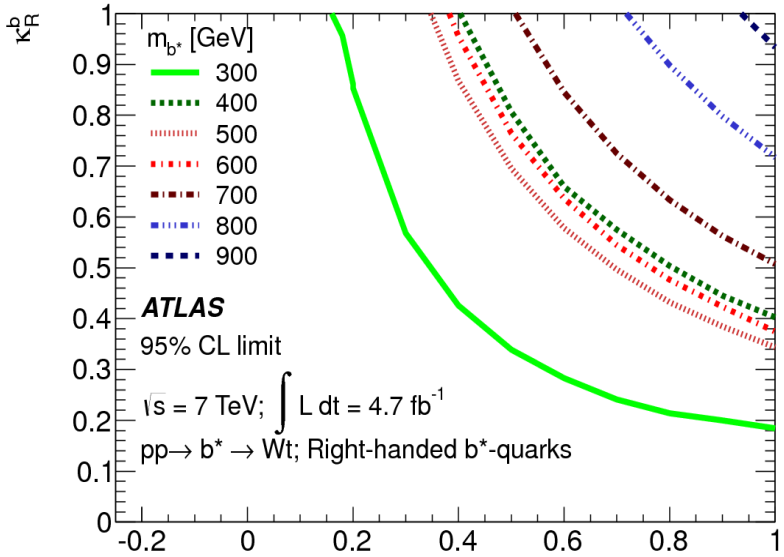
- Anti-kt 0.4 reco jets, JVF>0.75
- Single lepton trigger match required (for at least one lepton in dilepton case)
- No electron in barrel-endcap transition 1.37<h<1.52
- Isolation and overlap removal (veto event with e-μ sharing a track, remove μ within DeltaR<0.4 with a jet, remove first jet within DeltaR<0.2 with an electron, remove electron still having jets in DeltaR<0.4 cone)
- No b-tag in dilepton channel since the dominant background is ttbar
- W+jets estimated from data:
  - Normalization factor from charge asymmetry between W+ and W- production in 3 jets events, no b-tag
  - Flavor composition factor from 2 jet events comparing predicted yields to data with and without b-tag requirement
  - Previous factors applied to b-tagged W+3-jet events
- In reconstructed mass distribution
  - Hatched band shows the uncertainty due to the background normalisation
  - Last bincontains overflow
  - Neutrino momentum is set to 0

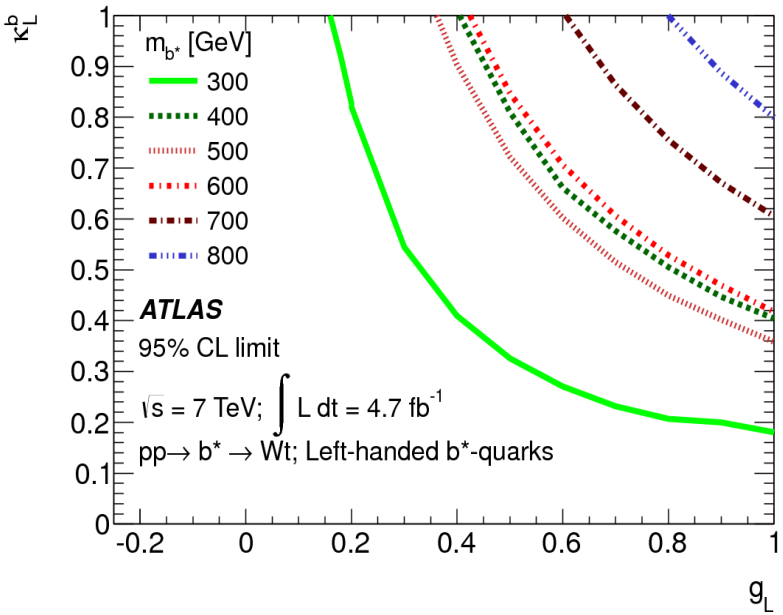
ATLAS arXiv:1301.1583
Phys. Lett. B 721 (2013) 171-189

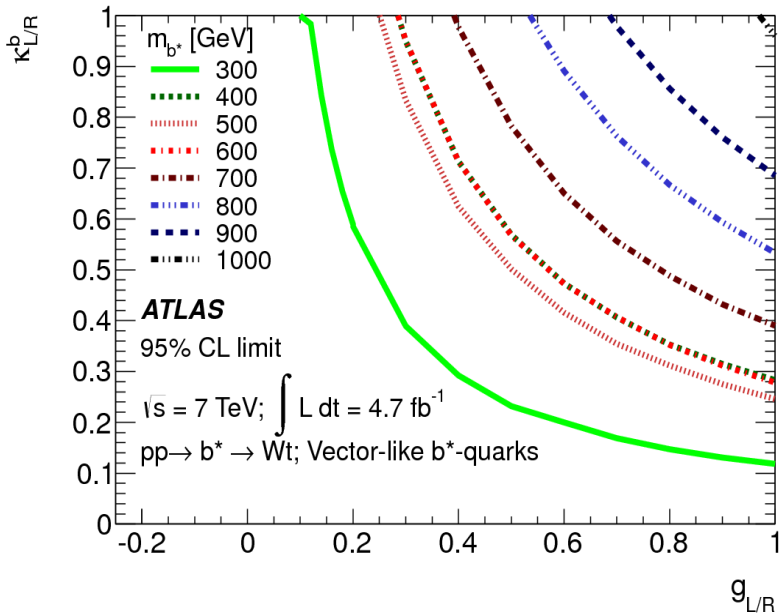
Single bottom-like quark

- Main systematic uncertainties
  - JES (2-7% per jet + 2-5% for b quark presence), JER, JRE, b-tag
  - Jet energy scale (p_T,η), largest impact on the limit setting (broadens both HT and reconstructed mass distributions)
- Bayesian analysis (flat prior)
- Cross section parametrized as a function of couplings for each mass point

Model	Limit Obs (exp)
$k^b_L=g_L=1$	870 (910) GeV
$k^b_R=g_R=1$	920 (950) GeV
$k^b_L=g_L=k^b_R=g_R=1$	1030 (1030) GeV



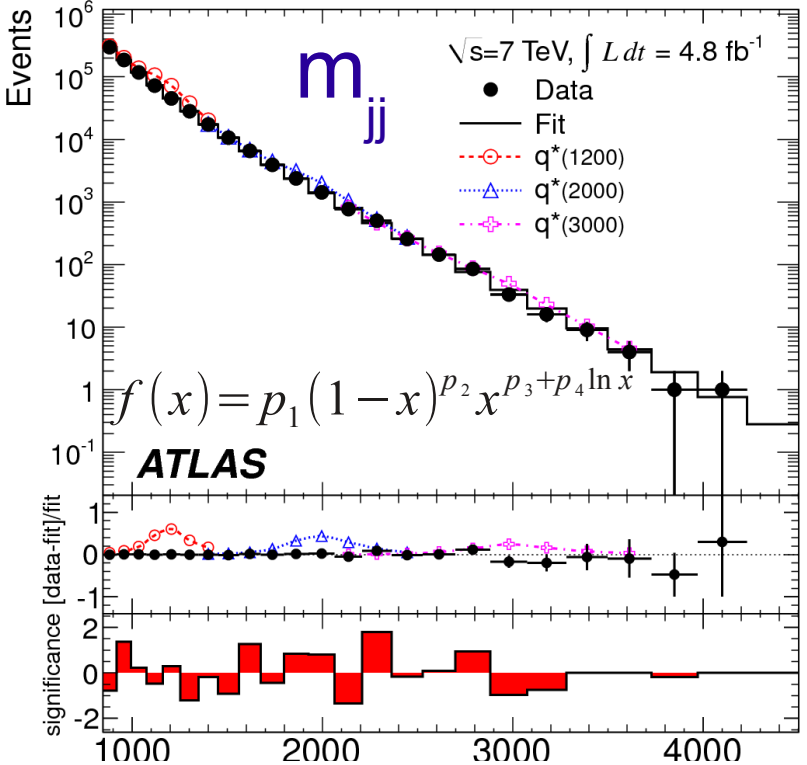


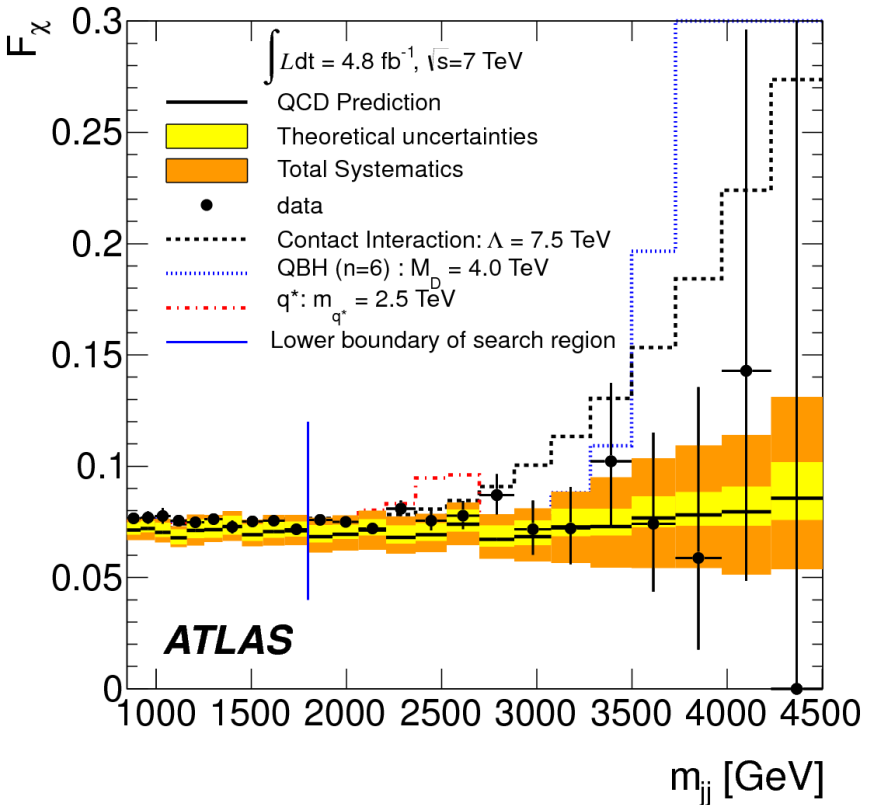


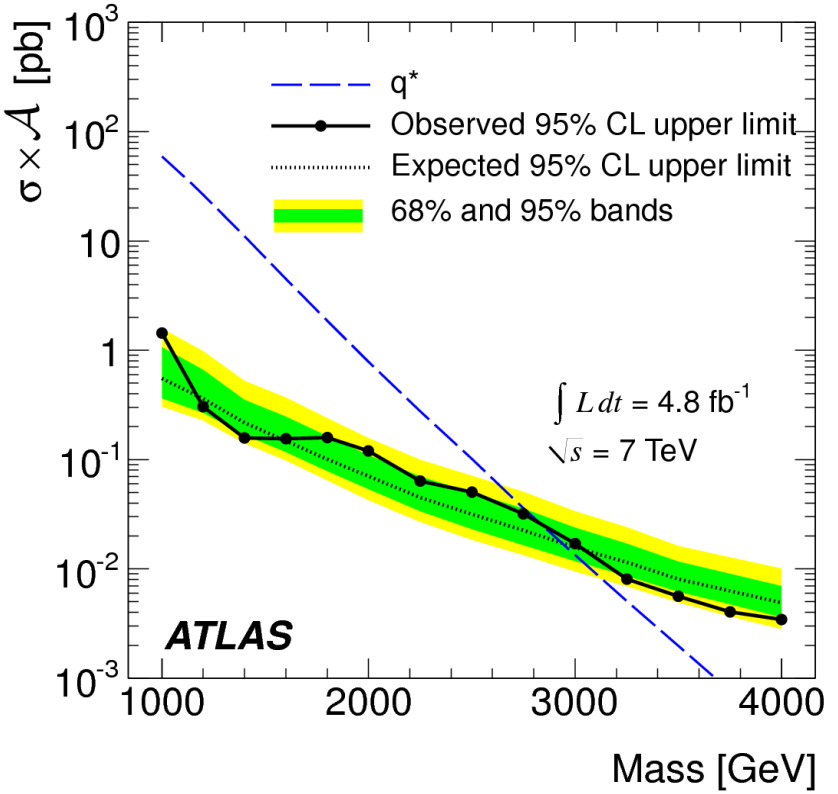
4.8 fb^{-1} @ 7 TeV

ATLAS JHEP01(2013)029

Excited quarks in dijet mass studies







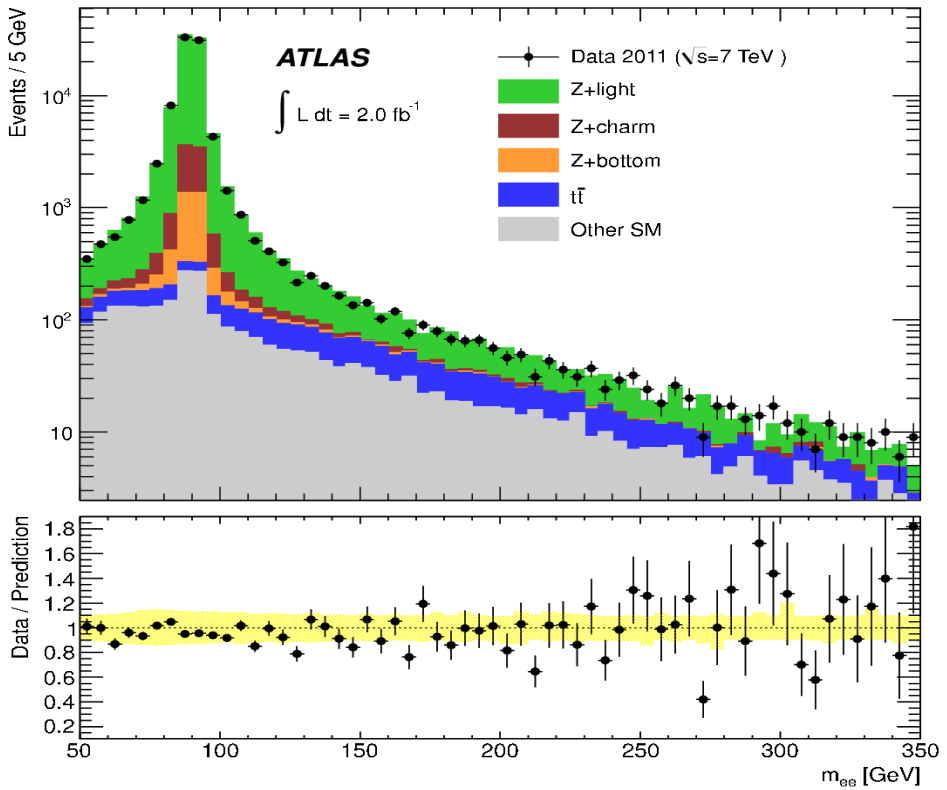
m_{q^*}>2.83 (2.94) TeV

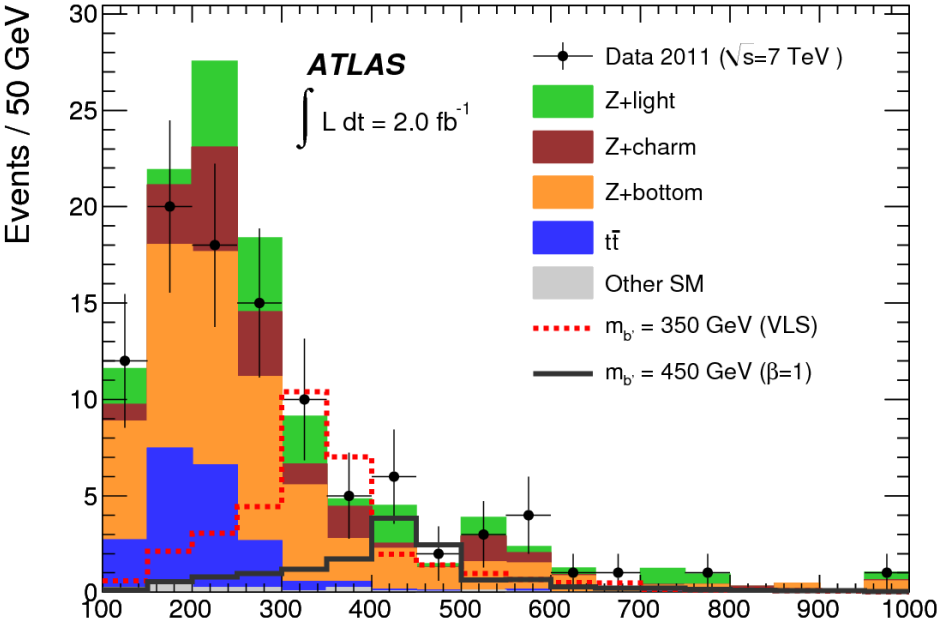
$$F_\chi(m_{jj}) = \frac{dN_{cent}/dm_{jj}}{dN_{tot}/dm_{jj}}$$

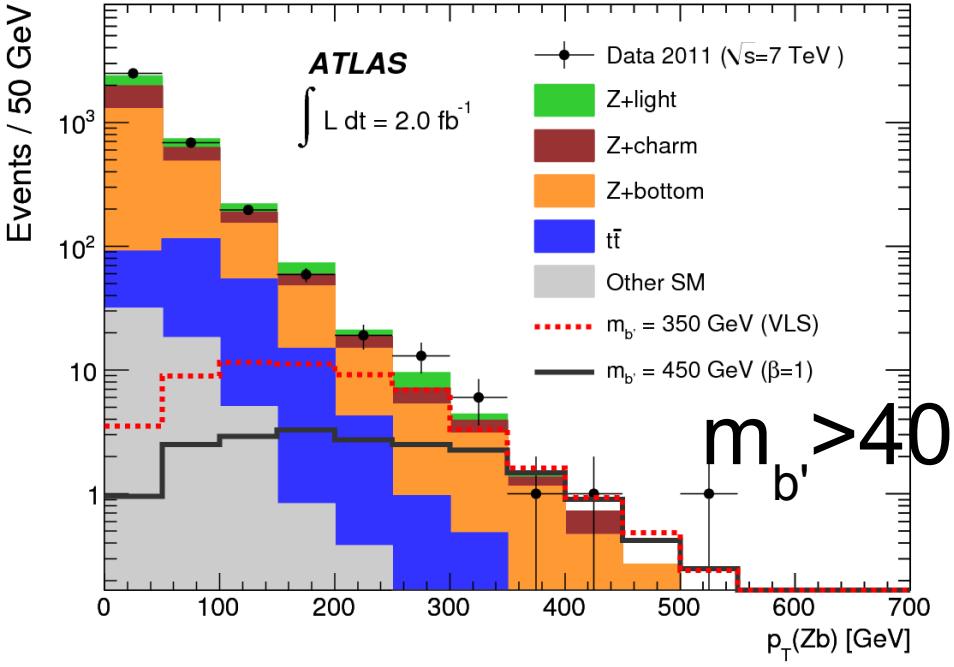
ATLAS Phys.Rev.Lett. 109 (2012) 071801

2.0 fb^{-1} @ 7 TeV

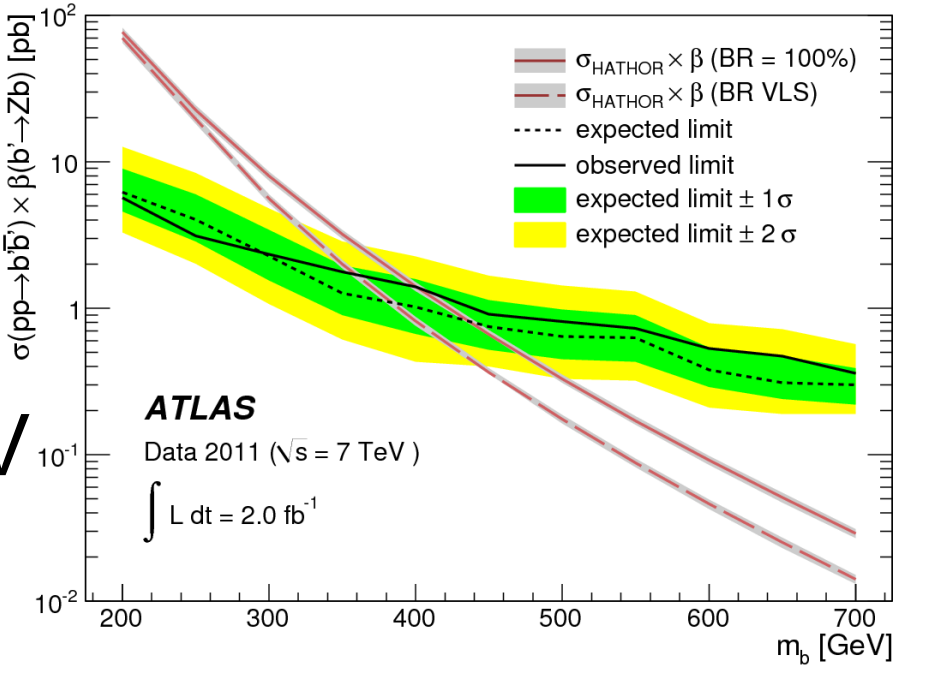
b'→Zb







$m_{b'}$>400 GeV



Extension of the Standard Model:

ATLAS-CONF-2012-130

4.7 fb^{-1} @ 7 TeV

$T_{5/3}$,b',4 tops in same-sign dileptons

Chiral 4th generation

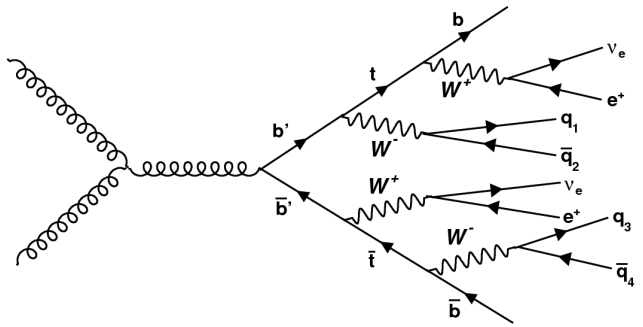
- Gluon-gluon fusion Higgs production cross section enhanced but suppressed H→γγ
- An heavy Dirac neutrino might open invisible H decays
  - Common reduction factor to all BR
- In accordance with extended Higgs sector
  - Two-Higgs-Doublet models

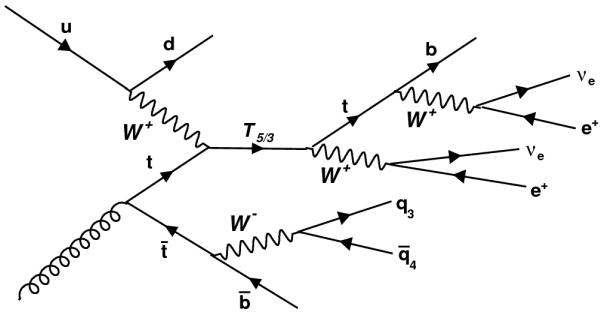
Top partner $T_{5/3}$

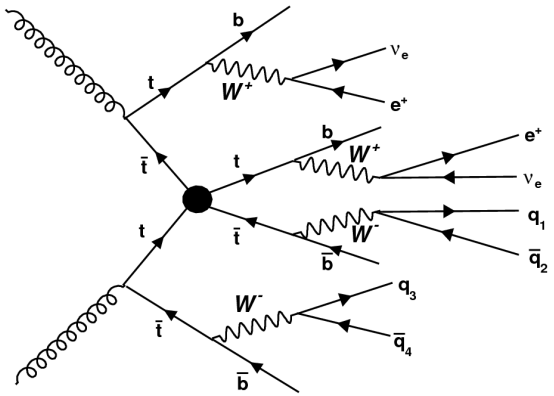
- Model where Higgs is a pseudo-Goldstone
- Equivalent b' kinematic for pair production
- Single production with different coupling constant λ=1, λ=3 for $tWT_{5/3}$ vertex

Production of 4 tops

- Production in SM of the order of ~1fb @ 7 TeV
  - Enhanced in many models including composite top
- Contact interaction with right-handed top quarks





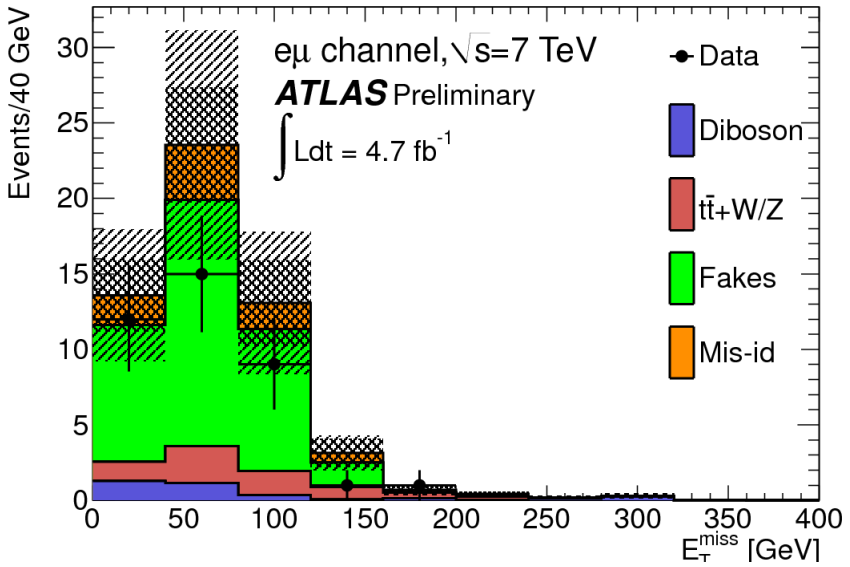


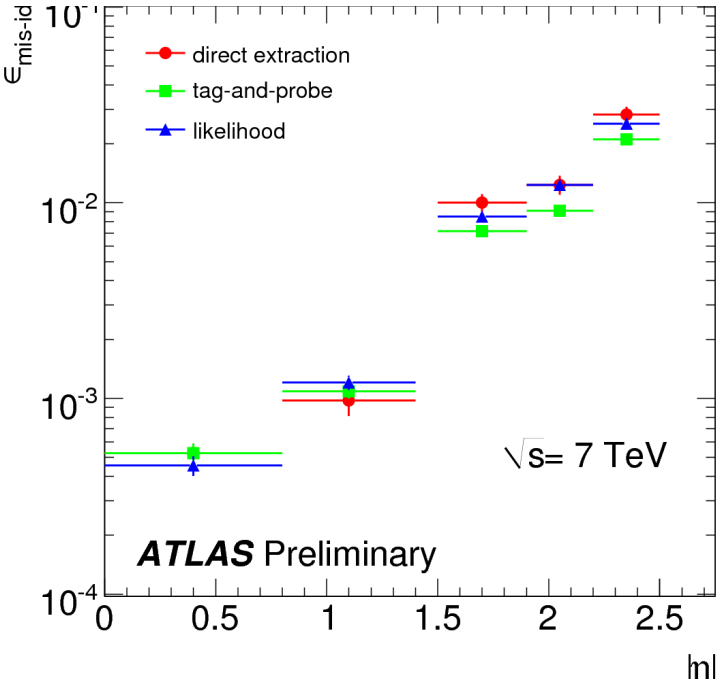
$T_{5/3}$,b',4 tops in same-sign dileptons

Preselection:

- ≥ 2 isolated leptons (ee, e) with same-sign, sorted by p_T
- muon (electron) with p_T>20 GeV, |η|<2.5 (E_T>25 GeV, |η|<2.47, no transition region) at least one matching trigger
- ≥ 4 calibrated anti-kt 0.4 jets with p_T>25 GeV, |η|<2.5, JVF>0.75
- ≥ 5 tracks associated to primary vertex
- ≥ 1 jets b-tagged (70% efficient algorithm, mis-tag<1%)

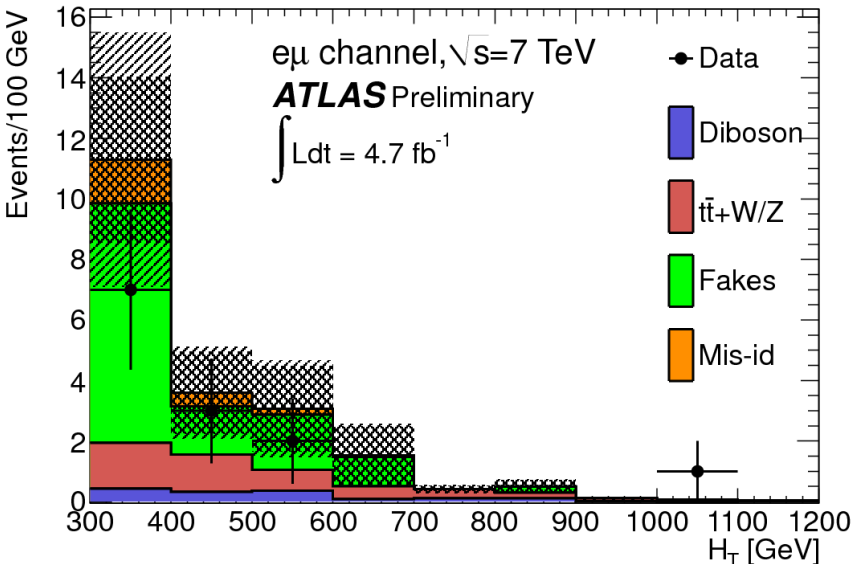
4.7 fb^{-1} @ 7 TeV





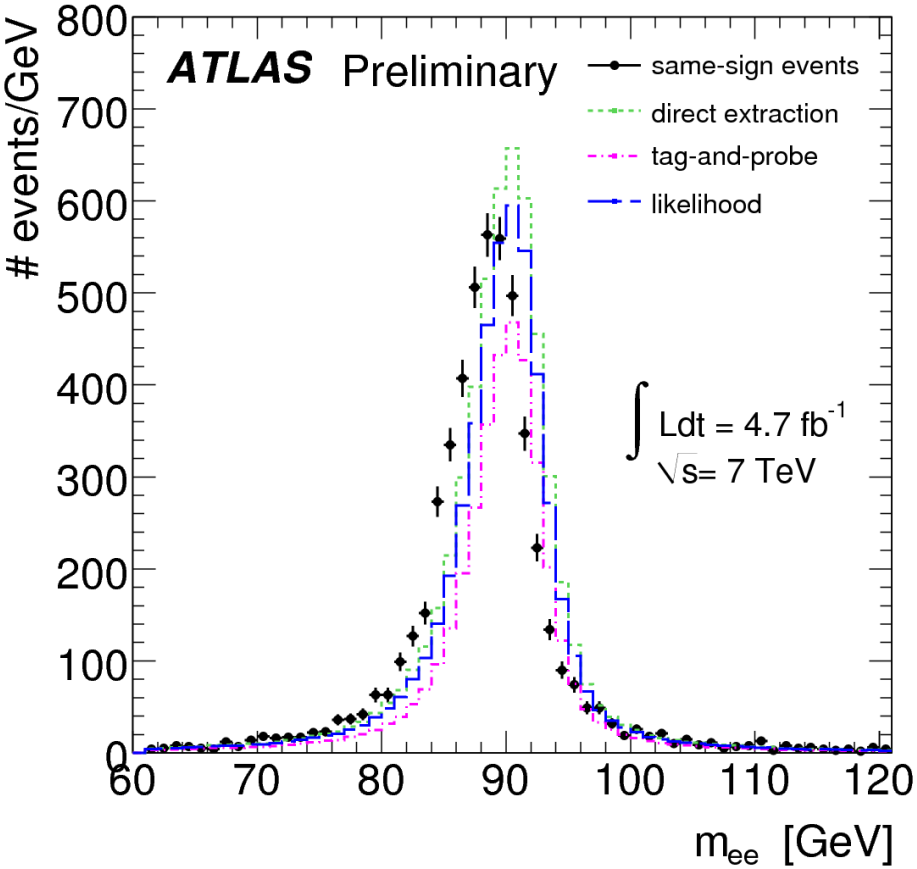
$T_{5/3}$,b',4 tops in same-sign dileptons - selection

- Primary vertex the one with highest summed track pT^2 with pT>0.4 GeV
  - ≥ 5 tracks associated to primary vertex
- Muon with p_T>20 GeV, |η|<2.5
  - Isolation: remove muons DeltaR<0.4 from any selected jet, cuts on transverse energy in 0.2 cone (4 GeV), and on transverse track momentum in 0.3 cone (2.5 GeV), cosmic rejection (angle >3.1 rad)
- Electron with E_T>25 GeV, |η|<2.47, no transition region 1.37<|η|<1.52
  - Isolation: remove closest DeltaR<0.2 jet, remove electron close DeltaR<0.4 to a jet, ET, eta dependent cuts on transverse energy in 0.2 cone (1.4-3.7 GeV), and on transverse track momentum in 0.3 cone (1-1.05 GeV)
- Reject events with e and μ sharing a track.
- Use HT, scalar sum of pT of all leptons and jets



$T_{5/3}$,b',4 tops in same-sign dileptons - backgrounds

- Background from Wγ+jet is negligible
- Charge mis-id parametrized in |η| and estimated in data events from Z bosons, with electron pairs in 81,101 GeV invariant mass window, with three different methods: tag-and-probe, direct extraction, and likelihood.
- In likelihood method all electron pairs are used (same sign and opposite)
  - Build a function of charge mis-id rates in a 2-D |η| grid
  - Minimization provide charge mis-id rates
  - Gives best agreement in the closure test
    - compare reweighted opposite-sign pairs, and reconstructed same-sign pairs (shifted to lower values due to the energy loss from radiated photons)

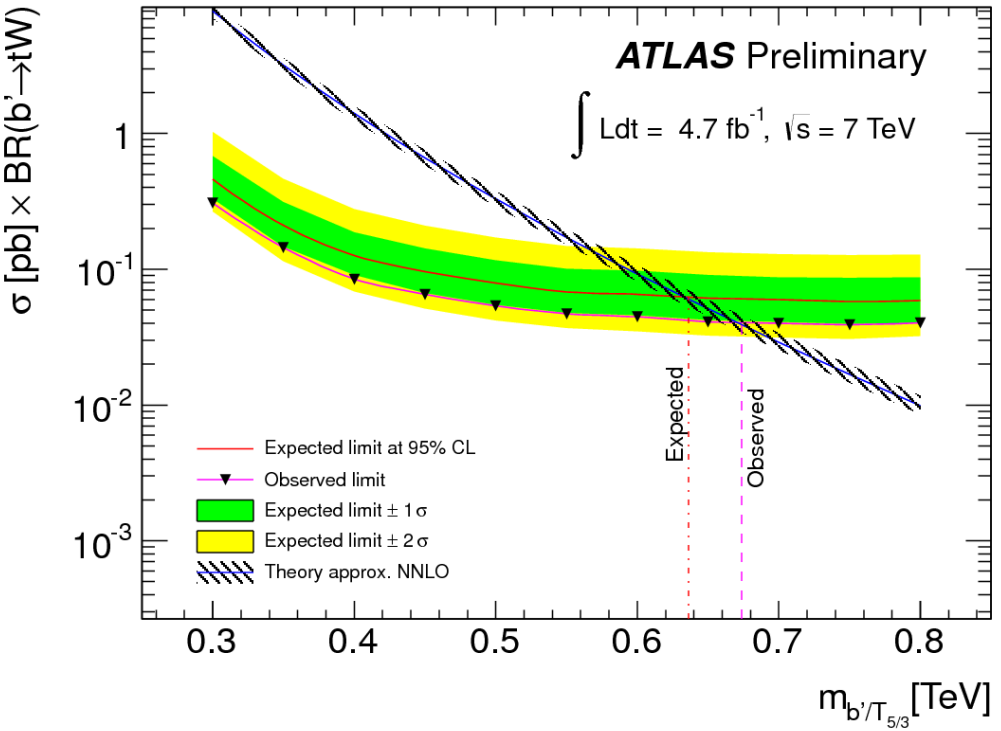


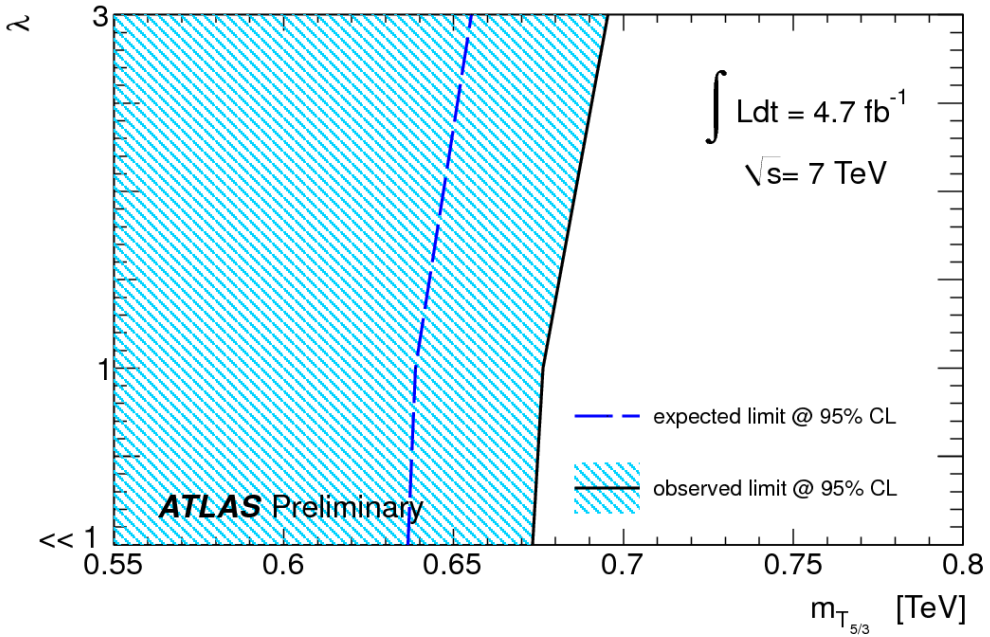
$T_{5/3}$,b',4 tops in same-sign dileptons - backgrounds

- Use matrix method for estimating mis-reconstructed leptons. Loose samples are selected by applying a looser isolation cut for electrons and removing isolation for muon
- Real rates from tag-and-probe with Z events where the overlap removal between leptons and jets is applied with loose leptons
- Fake rates for electrons from at least one jet and exactly one loose electron, Etmiss<20 GeV, minimal distance cut, overlap with loose leptons
- Fake rates for muons from low transverse W mass region: mT(W)<20 GeV, ETmiss+mT(W)<60
- Run on loose selected sample applying weights as obtained by inverting the matrix

$$\begin{bmatrix} N_{TT} \\ N_{TA} \\ N_{AT} \\ N_{AA} \end{bmatrix} = \begin{bmatrix} r_1 r_2 & r_1 f_2 & f_1 r_2 & f_1 f_2 \\ r_1(1-r_2) & r_1(1-f_2) & f_1(1-r_2) & f_1(1-f_2) \\ (1-r_1)r_2 & (1-r_1)f_2 & (1-f_1)r_2 & (1-f_1)f_2 \\ (1-r_1)(1-r_2) & (1-r_1)(1-f_2) & (1-f_1)(1-r_2) & (1-f_1)(1-f_2) \end{bmatrix} \begin{bmatrix} N_{RR}^{ll} \\ N_{RF}^{ll} \\ N_{FR}^{ll} \\ N_{FF}^{ll} \end{bmatrix}$$

ATLAS-CONF-2012-130





Main systematic uncertainties:

- MC background cross sections 30-50%
- Misreconstructed leptons 30-50%
- Charge mis-id 12%

Backgrounds	Channel ee	Channel $e\mu$	Channel $\mu\mu$
Mis-id	$0.13 \pm 0.04 \pm 0.02$	$0.23 \pm 0.04 \pm 0.03$	—
Fakes	$0.5 \pm 1.1 \pm 0.3$	$0.8 \pm 1.1 \pm 0.3$	$0.13 \pm 0.13 \pm 0.04$
Diboson			
• WZ/ZZ+jets	$0.19 \pm 0.20 \pm 0.07$	$0.34 \pm 0.21 \pm 0.13$	$0.28 \pm 0.22 \pm 0.10$
• $W^{\pm}W^{\pm}$+2 jets	$0.06 \pm 0.03 \pm 0.03$	$0.07 \pm 0.03 \pm 0.03$	$0.03 \pm 0.02 \pm 0.03$
$t\bar{t} + W/Z$			
• $t\bar{t}W$(+jet)	$0.23 \pm 0.02 \pm 0.07$	$0.79 \pm 0.04 \pm 0.24$	$0.57 \pm 0.04 \pm 0.18$
• $t\bar{t}Z$(+jet)	$0.17 \pm 0.02 \pm 0.09$	$0.61 \pm 0.03 \pm 0.31$	$0.33 \pm 0.02 \pm 0.17$
• $t\bar{t}W^{\pm}W^{\mp}$	$0.008 \pm 0.001 \pm 0.002$	$0.023 \pm 0.001 \pm 0.007$	$0.016 \pm 0.001 \pm 0.005$
Total	$1.3 \pm 1.1 \pm 0.3$	$2.9 \pm 1.1 \pm 0.5$	$1.36 \pm 0.26 \pm 0.27$
Observed	2	2	0

Constrained parameter	95% C.L. limits Expected	Observed
b' / $T_{5/3}$ pair production		
b' mass or $T_{5/3}$ mass for $\lambda \ll 1$	> 0.64 TeV	> 0.67 TeV
$T_{5/3}$ single and pair production		
$T_{5/3}$ mass for $\lambda = 1$	> 0.64 TeV	> 0.68 TeV
$T_{5/3}$ mass for $\lambda = 3$	> 0.66 TeV	> 0.70 TeV
Four top quark event production		
Four top quark production cross-section	< 90 fb	< 61 fb

ATLAS-CONF-2013-018

t'→Ht (l+jets)

Preselection:

- Exactly one isolated muon (electron) with p_T>25 GeV, |η|<2.5 (E_T>25 GeV, |η|<2.47, no transition region) matching trigger
- ≥ 4 calibrated anti-kt 0.4 jets with p_T>25 GeV, |η|<2.5, JVF>0.5
- ≥ 5 tracks associated to primary vertex
- ≥ 2 jets b-tagged (70% efficient algorithm, ~130 light jet, ~5 charm jet rejection) to fully exploit signatures ***H→bb̄, Z→bb̄***
- E_T^{miss}>20 GeV and $E_T^{miss}+m_T$>60GeV

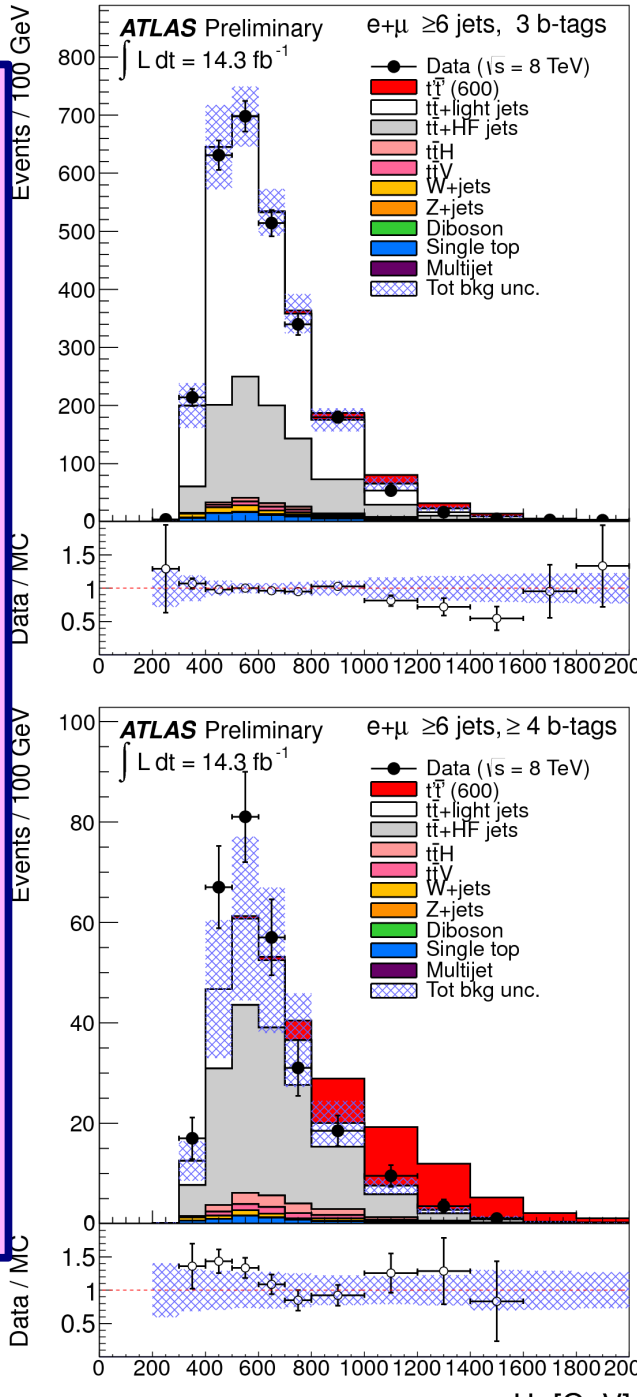
Backgrounds:

- tt̄ + up to 3 partons (with MLM matching)
- W+up to 5 partons (normalized to data using asymmetry between W^+ +jets W^- +jets in pp production)
- Multijets fake estimates from data with matrix method
- Small contributions from single top, Z+jets, diboson (WW, WZ, ZZ), ttW, ttZ, ttH

Analysis: sensitive to channels HtHt̄, ZtHt̄, WbHt̄, ZtZt̄, WbZt̄

- ≥ 6 jets, ≥ 2 b-tagged jets
- Three signal regions based on b-tags (=2, =3, ≥ 4)
- Simultaneous fit to the three H_T distributions to determine scaling factors for tt̄ + light jets and tt̄ + heavy-flavor jets

14.3 fb^{-1} @ 8 TeV



ATLAS-CONF-2013-018

t'→Ht (l+jets)

14.3 fb^{-1} @ 8 TeV

Leptons:

- **Lepton track longitudinal impact parameter, z0 < 2mm**
- **Muon Isolation: remove muons DeltaR<0.4 from any selected jet**
- **Electron Isolation: remove closest DeltaR<0.2 jet, remove electron close DeltaR<0.4 to a jet**

Trigger:

- **Low pT threshold trigger at 24 GeV, include isolation, inefficient at high pT; recovered by high pT threshold trigger (36 GeV for muon, 60 GeV for electron)**

Samples:

- **tt+jets ALPGEN v2.13 (LO) CTEQ6L1 PDF set + HERWIG v6.520,m(top)=172.5GeV, normalised to NNLO theoretical cross section (HATHOR) using MSTW2008NNLO PDF set**
- **MLM parton-jet matching scheme: avoid overlap between $t\bar{t}Q\bar{Q}$ events with heavy quarks generated from the matrix element and from parton-shower evolution (DR(Q,$\bar{Q}$)<0.4)**

Backgrounds:

- Matrix method: multijets faking an electron (photon conversion, jets with high EM fraction) or muon (from semileptonic b,c decays) estimated using tight sample (equivalent to analysis cuts) and loose sample (subset of the tight), obtained removing the isolation criteria. Real eff for electron (muon) is ~0.75 (~0.98) and fake is ~0.35 (~0.20)
- W+jets are scaled in the electron (muon) channel by a factor 0.83±0.10 (0.94±0.10), Wbb+jets, Wcc+jets by 1.41±0.35 (1.24±0.34), Wc+jets by 0.73±0.37 (0.98±0.34)
- ttbar+jets contribution after HT<700GeV control region fit: light jets 0.87±0.02; heavy-flavor jets 1.35±0.11. After signal region fit: light jets 0.88±0.02; heavy-flavor jets 1.21±0.08

t'→Ht (l+jets)

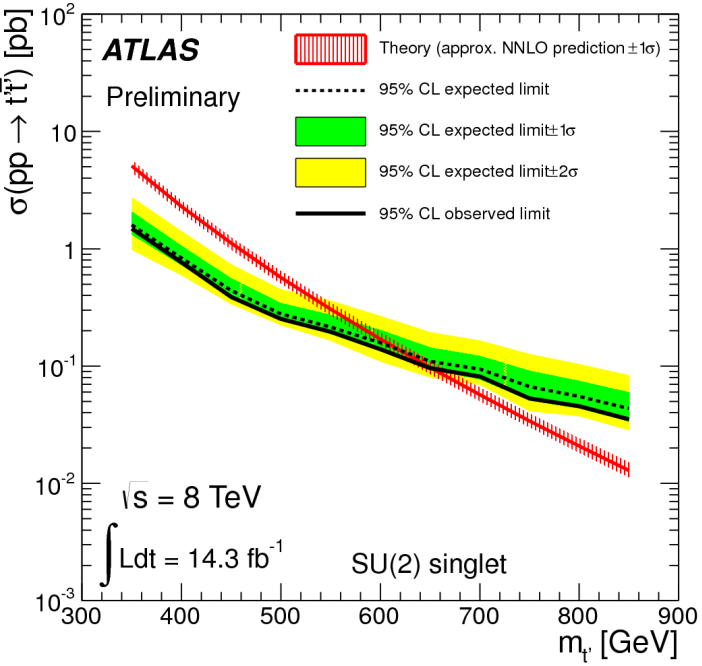
14.3 fb^{-1} @ 8 TeV

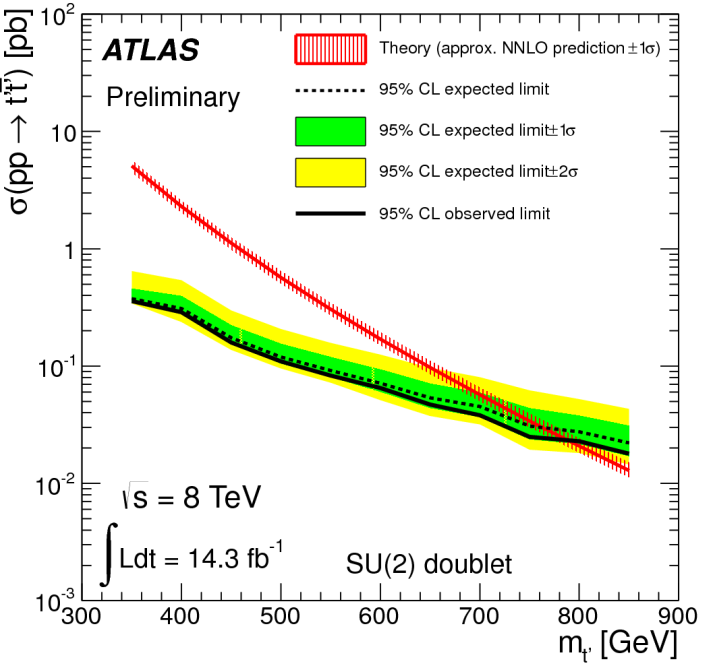
Systematic uncertainties:

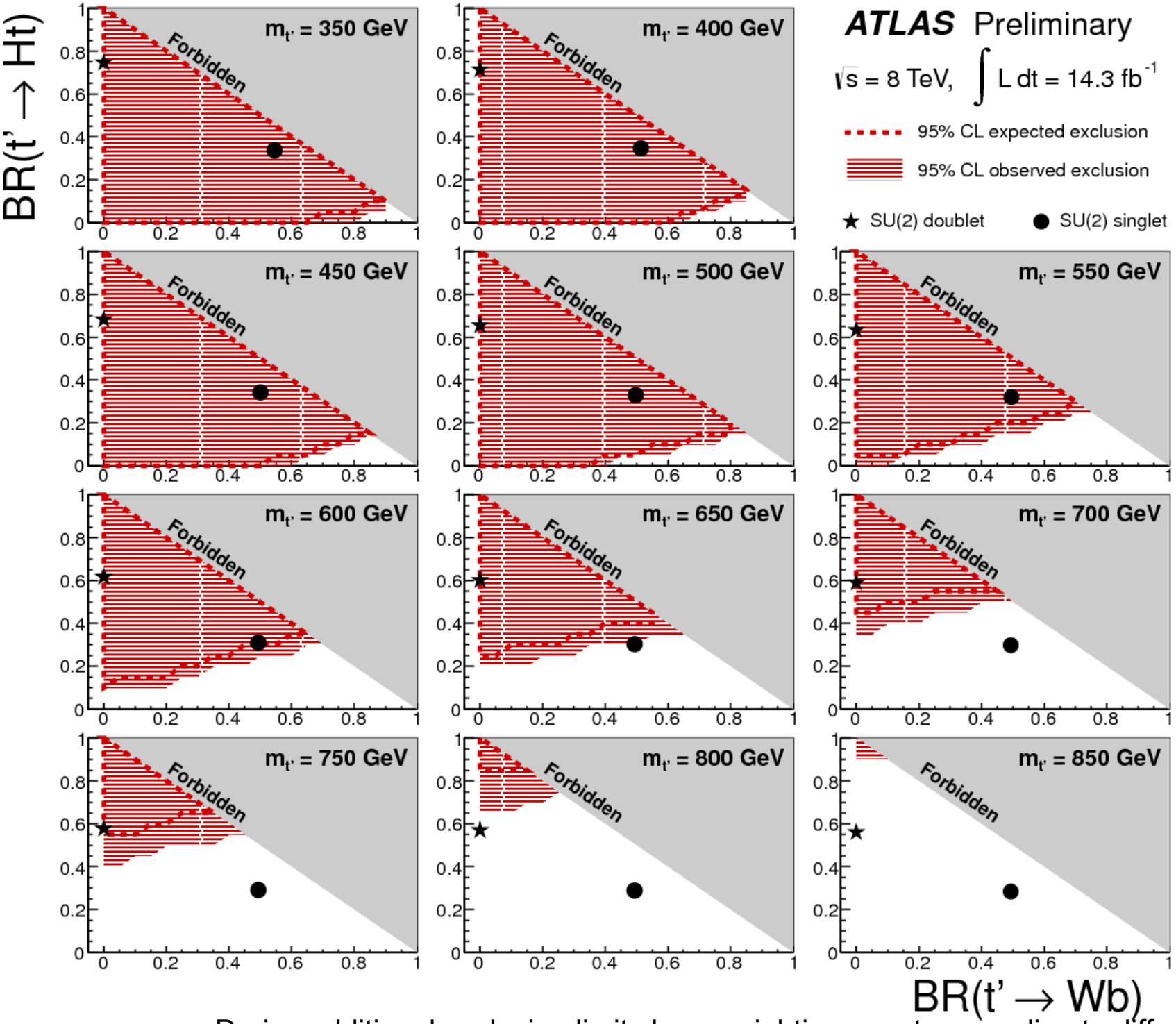
- Individual sources considered uncorrelated
- Correlation maintained across processes and channels
- Affecting only normalization, shape or both
- Main contributions
  - b-tagging efficiency 16%
  - c-tagging efficiency 11%
  - Jet energy scale 11%
  - $t\bar{t}$ modelling 11%
  - $t\bar{t}$+heavy flavor fractions 32%
  - $t\bar{t}$ cross section 10%
- Total uncertainty on ≥4 b-jet channel 21%
  - Reduction of 80% fitting $t\bar{t}$+jets scaling factors

Statistical analysis:

- No significant data excess
  - Upper limit on cross section x BR
- Use CL_s method to set 95% observed (expected) exclusion mass limits
- Weak-isospin doublet $m_{t'}$>709 (745) GeV
- Weak-isospin singlet $m_{t'}$>640 (615) GeV







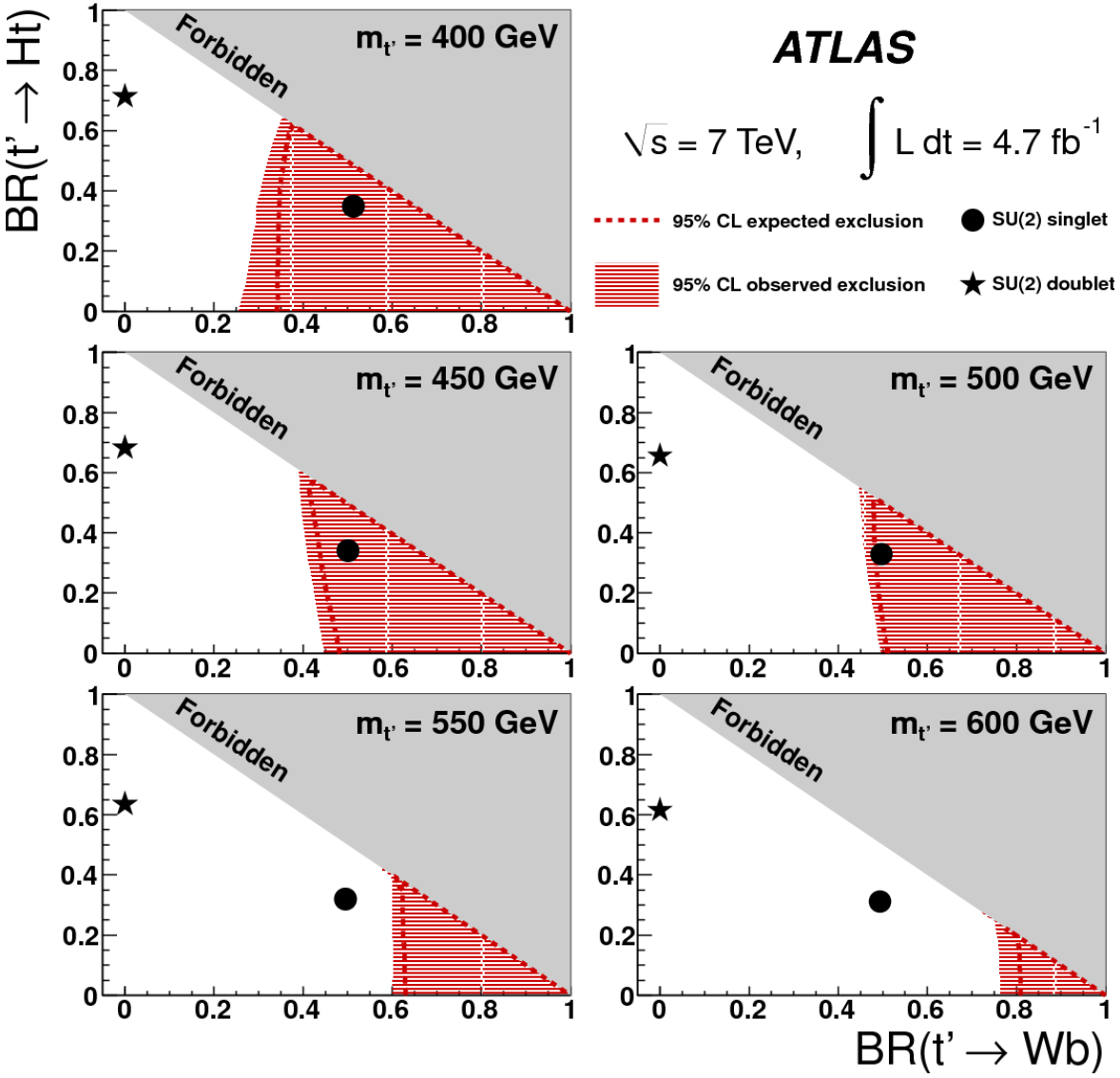
t'→Ht (l+jets)

Derive additional exclusion limits by reweighting events according to different BR

Phys. Lett. B 718 (2013)1284-1302

4.7 fb^{-1} @ 7 TeV

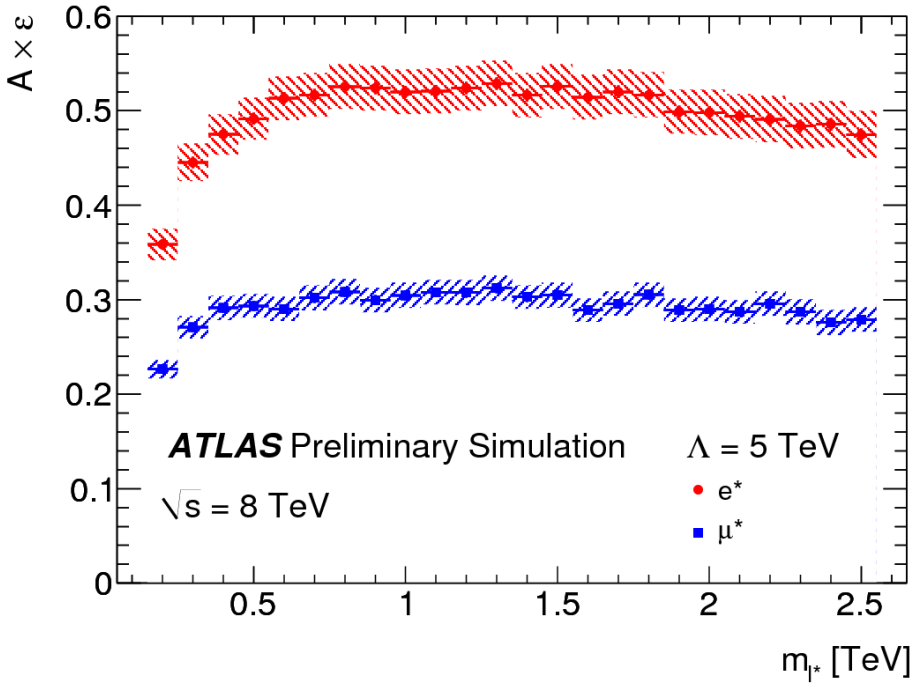
t'→Wb



ATLAS -CONF-2012-146

Excited leptons: e* and μ*

- Search for lepton compositeness in single excited lepton production
- Tight isolated photon p_T>30GeV, |η|<2.37, separation R(l,γ)>0.7
  - 75% efficiency
- p_T(e)>40,30 GeV, |η|<2.47 only first isolated, dielectron trigger
  - 85% efficiency
- p_T(μ)>25GeV, |η|<2.5, isolated, single μ trigger, opposite charge
  - 70% efficiency
- Keep highest invariant mass same-flavor lepton pair having m(ll)>110 GeV



Signal region	
m(l*)<900 GeV	m(llγ)>m(l*)+150 GeV
m(l*)≥900 GeV	m(llγ)>1050 GeV

ATLAS -CONF-2012-146

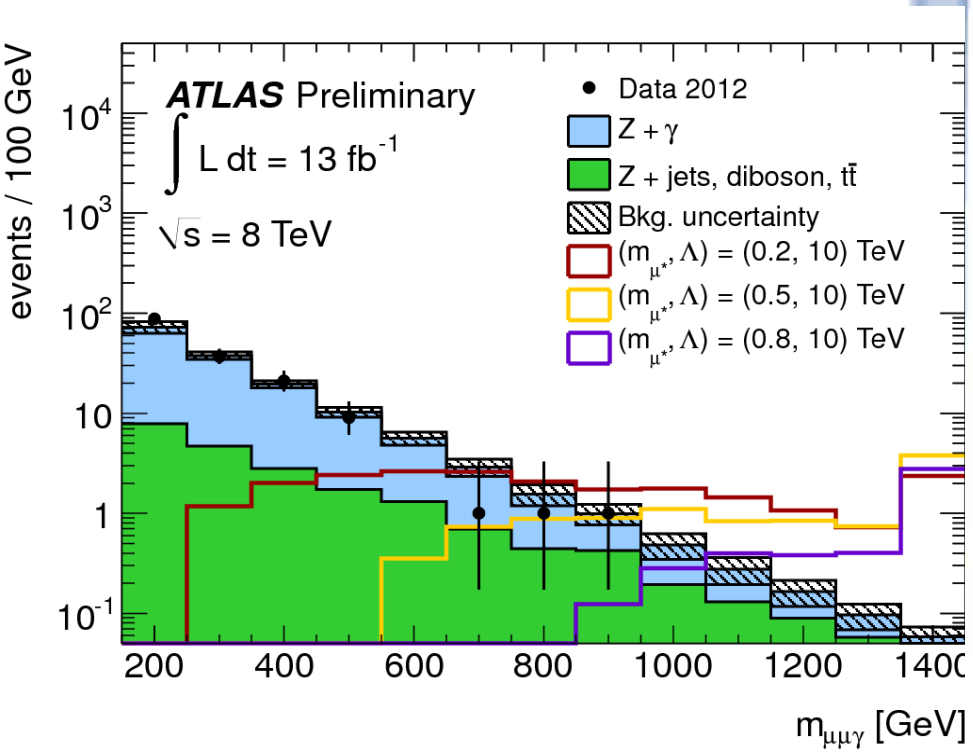
Excited leptons: e* and μ*

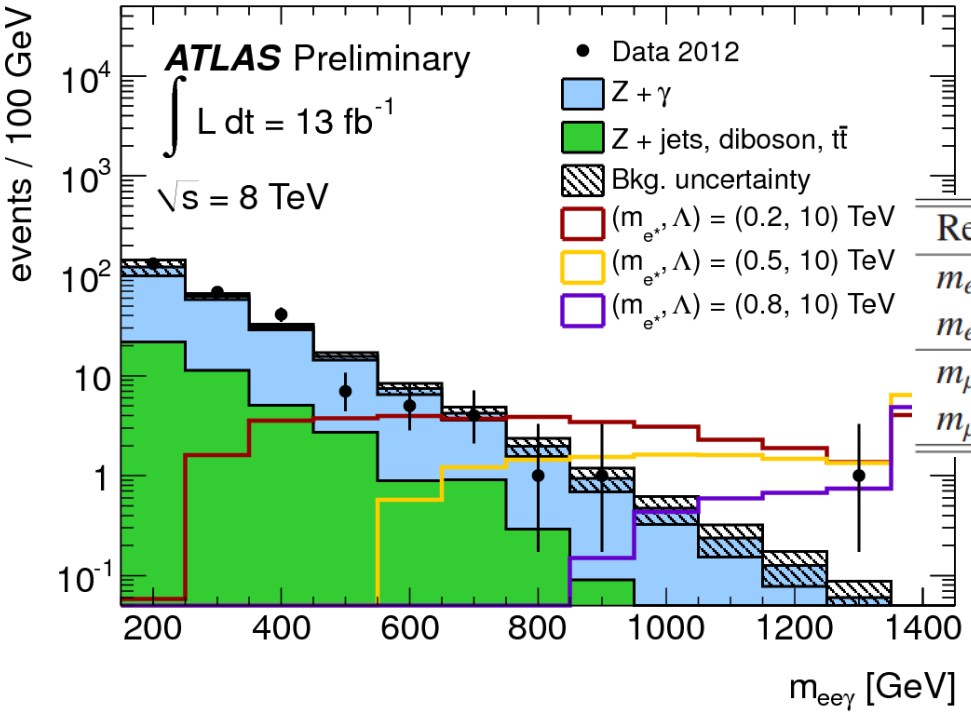
MC estimated backgrounds dominated by Z+γ

- Use signal depleted region 70<m(ll)<110 GeV to find scale factors for Z+jets

Channel: e* 0.51±0.09 μ* 0.65±0.09

Other contributions from $t\bar{t}$, diboson





Region [GeV]	$Z+\gamma$	Z + jets	other	total MC	data
$m_{ee} < 110$	1254 ± 20	360 ± 70	18.9 ± 1.4	1633 ± 70	1633
$m_{ee} > 110$	208 ± 10	24 ± 8	19.7 ± 1.6	252 ± 13	263
$m_{\mu\mu} < 110$	1118 ± 20	416 ± 60	17.7 ± 1.2	1552 ± 60	1552
$m_{\mu\mu} > 110$	137 ± 8	15 ± 5	8.3 ± 1.3	160 ± 10	159

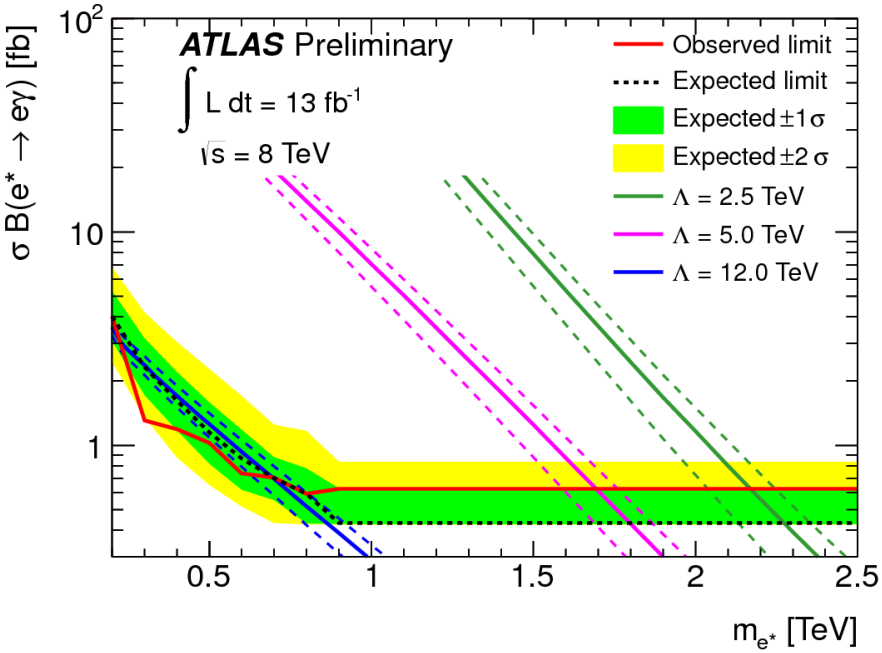
Excited leptons: e* and μ* - selection

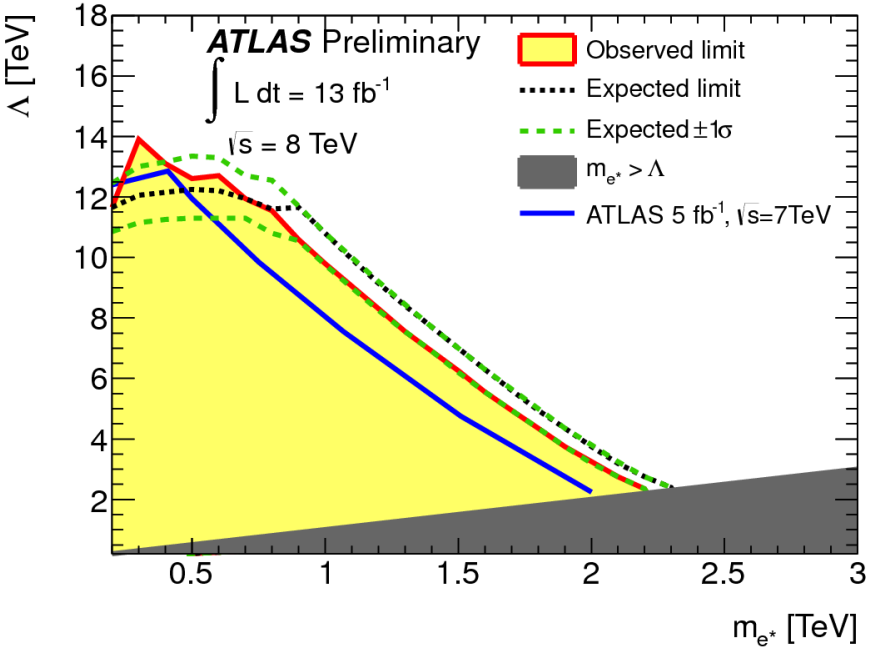
- Electrons (do not look at charge to minimize mis-id)
  - Dielectron trigger pT=35 GeV and pT=25 GeV
  - Reject in transition region
  - Identification criteria *medium*
  - B-layer hit on active modules
  - Isolation (independent of pT)
    - Sum of transverse energy around electron direction <7 GeV in R<0.2 cone
    - Excluded core and corrected for pile-up and shower leakage
- Muons
  - Hits on all (inner, middle, outer) muon spectrometer layers
    - reduced geometrical acceptance
  - Cosmic rays rejection |d0|<0.2 mm and |z0|<1mm
  - Isolation: sum (pT>1 GeV ID tracks in a R<0.3 cone)<0.05 pT(μ)
- Photons
  - Sum (transverse energies of the clusters in R<0.4 cone) < 10 GeV
  - Lepton photon separation suppress Drell-Yan events with FSR photons
  - Keep largest pT photon

Excited leptons: e* and μ*

Systematic uncertainties for m(l*)=200GeV (m(l*)>900GeV)

- Exponentials to fit shapes of Z+γ and of Z+jets: 6% (40%)
- Cross section of Z+γ 6% (8%)
- Luminosity 3.6%
- Photon efficiency 4%
  - Additional 4% for $p_T(\gamma)$>1 TeV



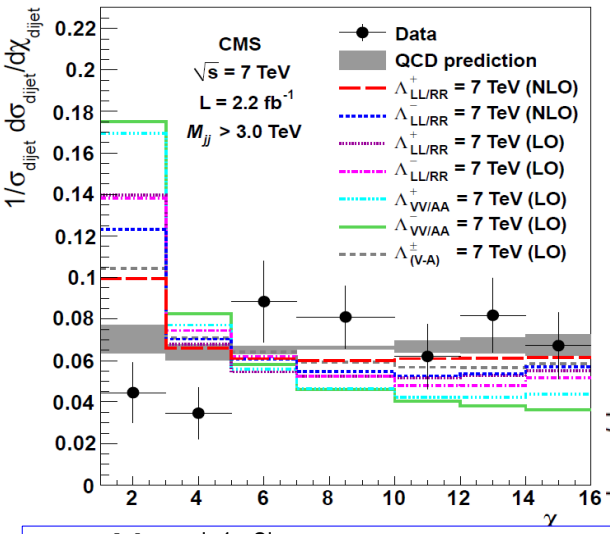


Excited leptons: e* and μ* - more details

- At fixed Λ the branching ratio $l^* \rightarrow l\gamma$ decreases rapidly with increasing l^* mass (competing with contact interaction $l^* \rightarrow l\bar{f}f$
  - At Λ=2 m_{l^*}=0.2 TeV BR($l^* \rightarrow l\gamma$)=30%
  - At Λ=2 m_{l^*}=2 TeV BR($l^* \rightarrow l\gamma$)=2.3%
- The control region represents at most 3% of the signal parameter-space for $m(l^*) \geq 200$ GeV
- The excess of background events found in the simulation in this control region is attributed to the mismodeling of the rate of jets misidentified as photons in the Z+jets simulation
- The Z+jets contribution is scaled such that the number of events in data is equal to the sum of Z+γ, tt, diboson, and scaled Z+jets.
- Limit calculation with Bayesian approach (flat positive prior on $\sigma B(l^* \rightarrow l\gamma)$),
  - Systematic uncertainties incorporated as nuisance parameters with Gaussian prior

q*(qg).... → Di Jets

- Search for **quark compositene** in dijet angular distribution in pp collisions at 7 TeV in **CMS 2011** data @LHC (luminosity 2.2 fb^{-1}) fo 0.4 TeV<M_{jj}<3TeV
- Variety of contact interaction color singlet models with NLO QCD corrections, new interactions betw quarks components at scale Λ >> quark masses
- Pp collisions produces events with two jets with high pT, and probe scattering at short distances
- Dijets angular distribution directly sensitive to dynamics of parton-parto scattering
- Signature: 2 particle-flow jets, primary vertex, |η|<2.5, m_{jj}>890 GeV
- Background: QCD



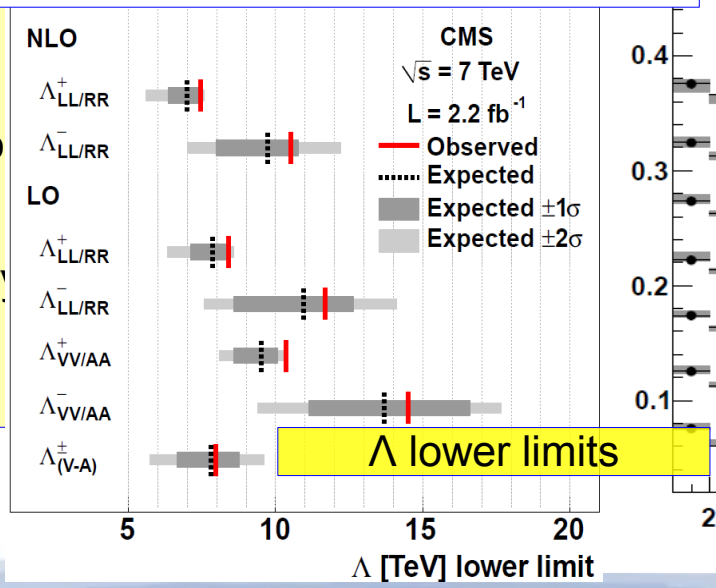
CMS EXO 11-017

arXiv:1202.5535v1[hep-ex]

10.1007/JHEP05(2012)055

$X_{jj}=e^{|y1-y2|}$

$y=1/2\ln[(E+p_z)/(E-p_z)]$



Λ lower limits