Search for Physics Beyond the Standard Model (non-SUSY) at ATLAS

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Motivation

Why does this talk have that funny title?

SUSY is the Answer => very **model-driven**

"non-SUSY": no compelling argument for any given model =>"signature-based" / **model agnostic**
+ key ideas not covered by SUSY searches
(e.g. alternate explanations of electroweak symmetry breaking,
KK resonances, production of new particles with macroscopic lifetimes)

By "signature-based searches," we mean a focus on what objects end in the the detector and how they are related:

look for extensions that combine familiar ingredients

leptons, jets, MET, photons...

in familiar ways

two-body resonances, X+MET...

convey sensitivity with specific interpretation in terms of benchmark models

but design inclusively for broad sensitivity, expecting surprises

This talk: recent ATLAS searches with up to 20/fb of 2012 data

two-body resonances

third generation searches

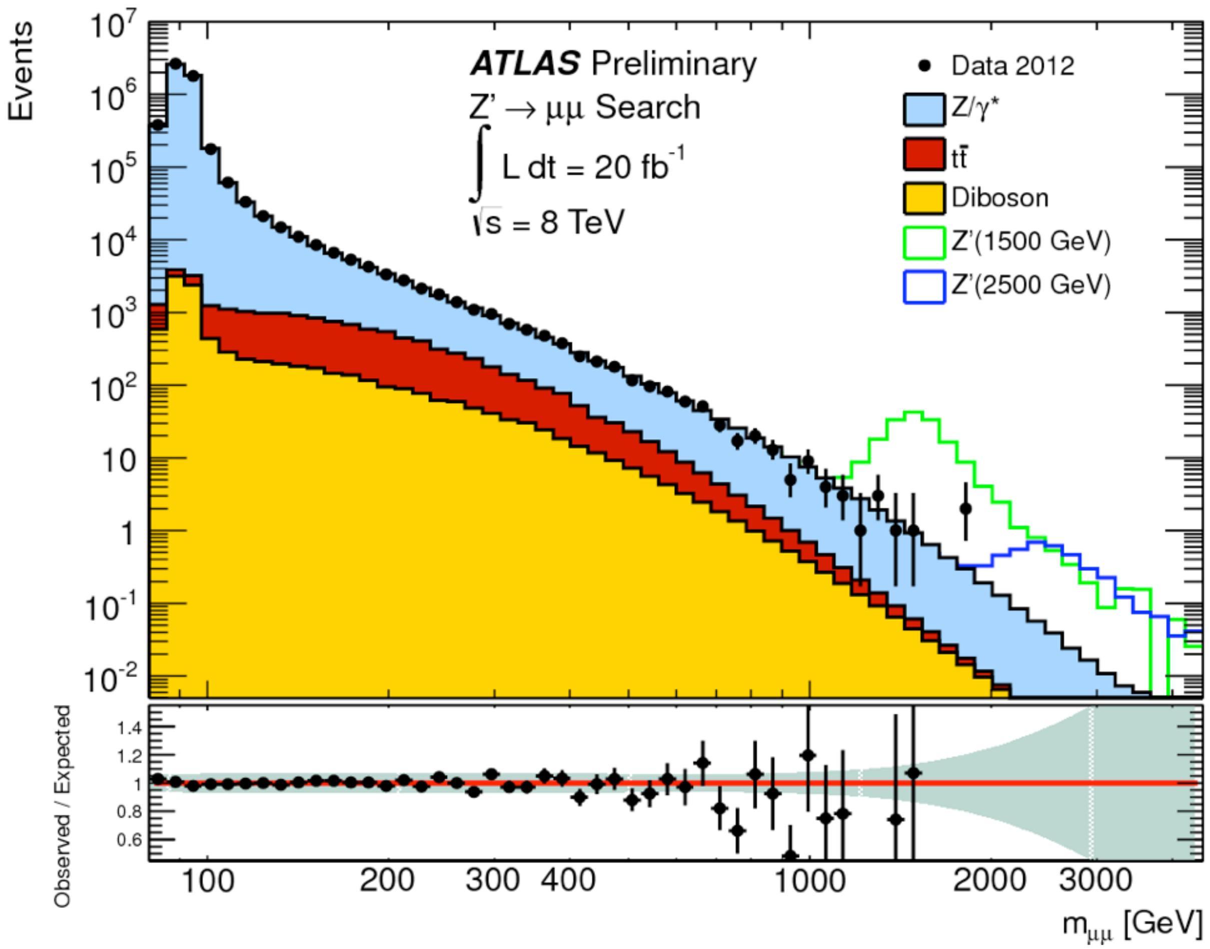
example of a general purpose search

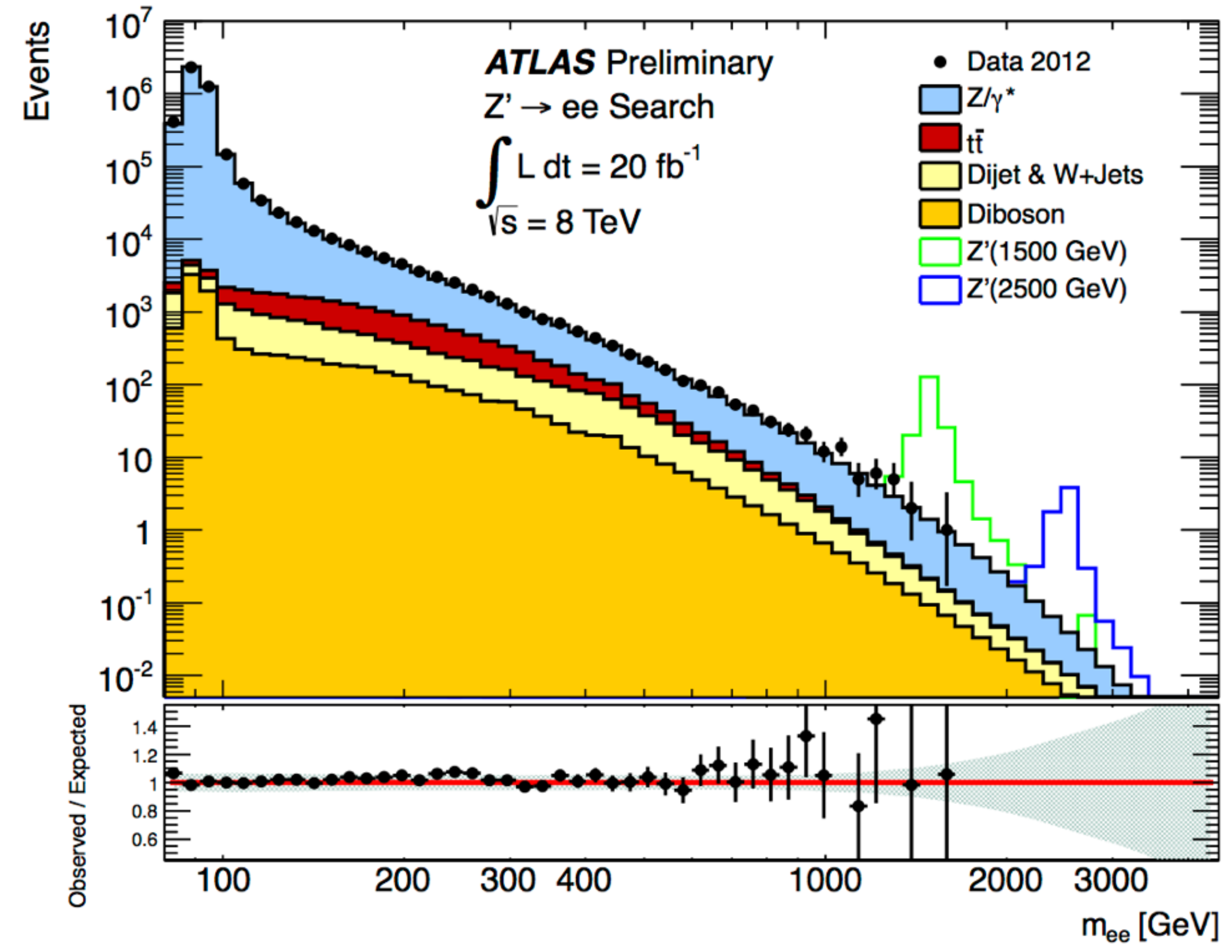
X+MET searches

Dilepton resonances

ATLAS-CONF-2013-017

Consummate signature-based search: well understood final states (two electrons or muons), clean SM prediction, many BSM models: GUTs (->U(1)), KK partners, Little Higgs, ...





Dielectron/dimuon example limits:

$m_{Z'_{SSM}} > 2.86$ TeV

$m_{Z'} > 2.38–2.54$ TeV for various E6-motivated Z's

$m_G > 2.47$ TeV for a RS1, $k/M_{Pl} = 0.1$.

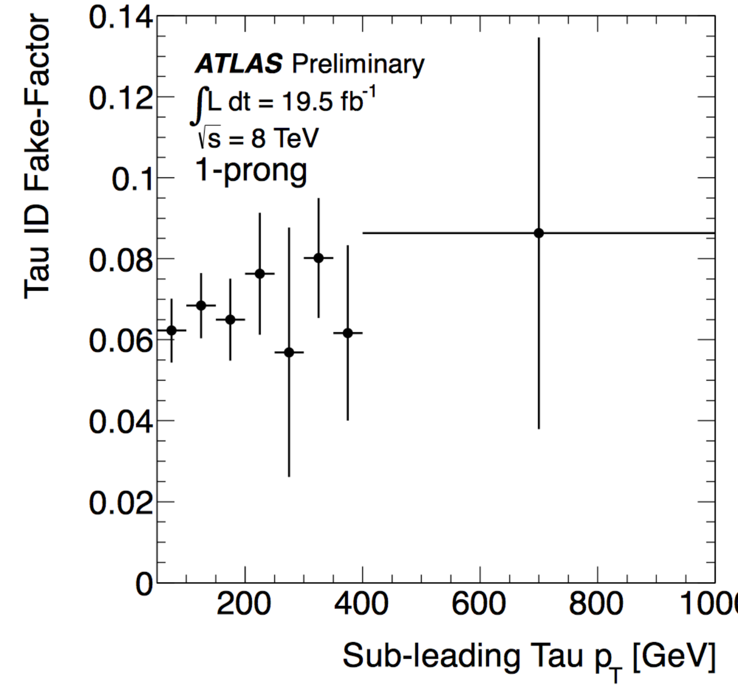
Ditau resonances

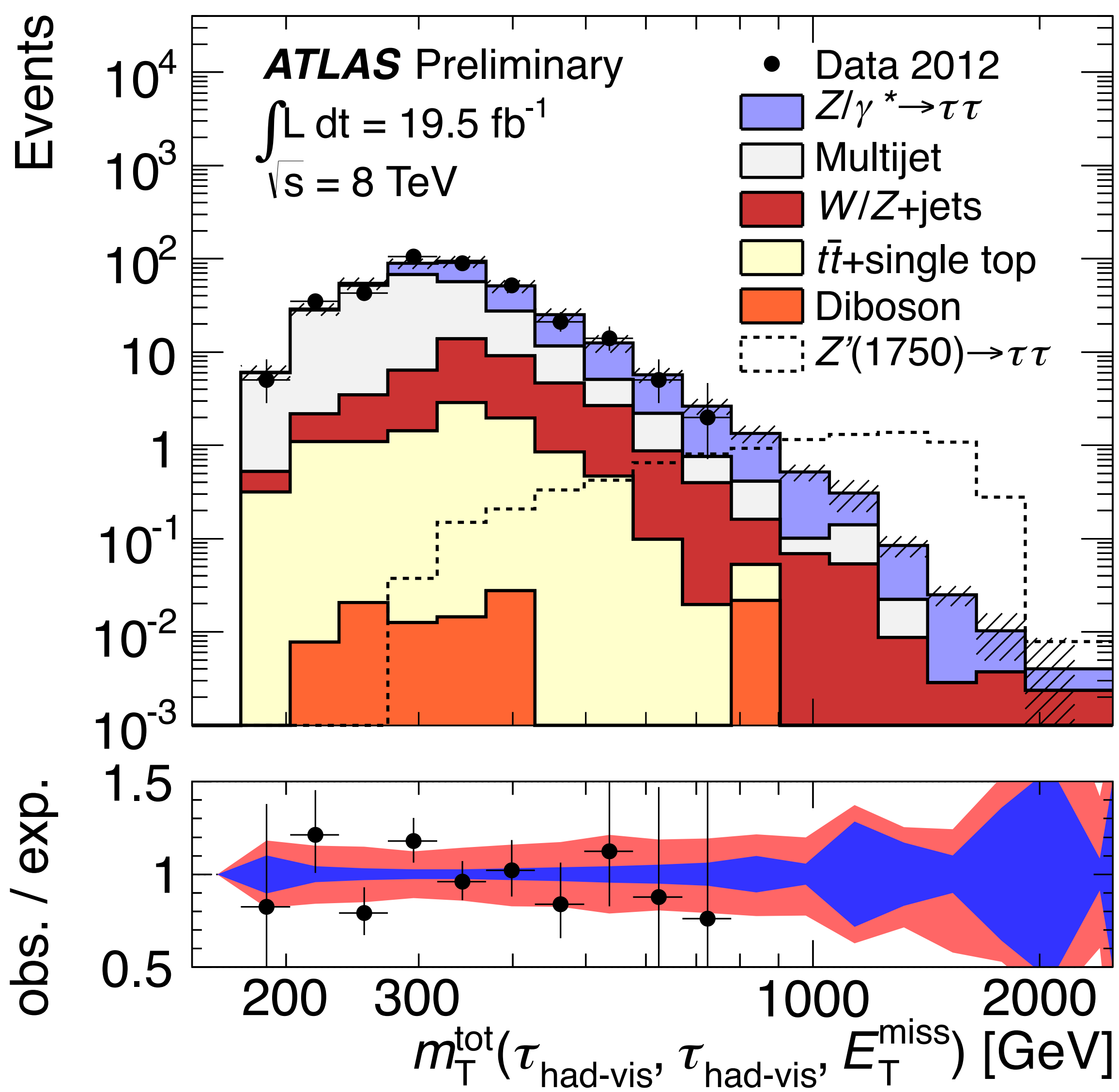
ATLAS-CONF-2013-066

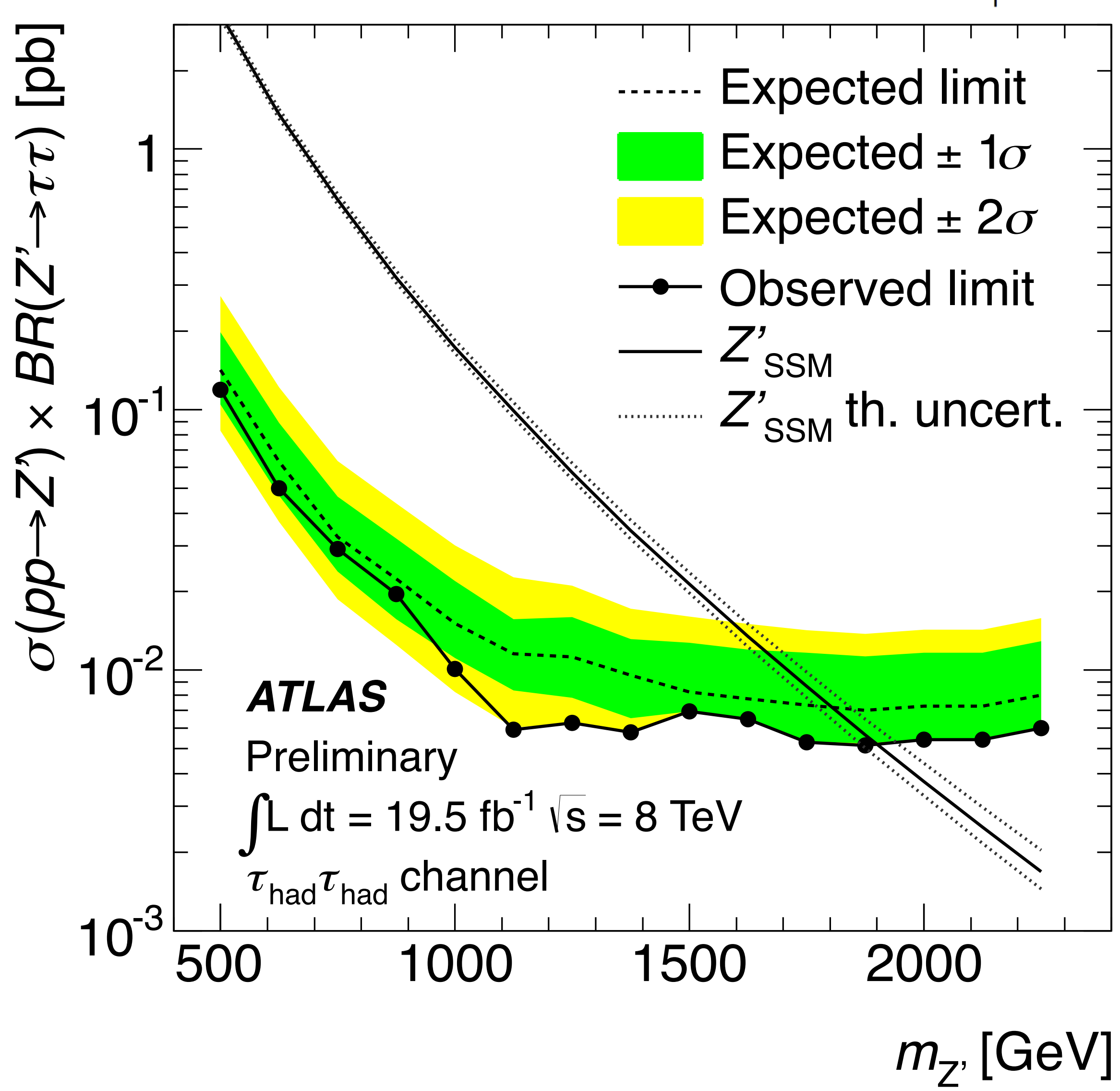
Analysis complements dielectric and dimuon searches in models where these are suppressed (e.g. for KK resonances in RS models)

Reconstruct fully hadronic taus (1- and 3-prong decays) and apply multivariate tau ID to reject hadronic backgrounds

Main backgrounds at high mass: Drell-Yan and multijets





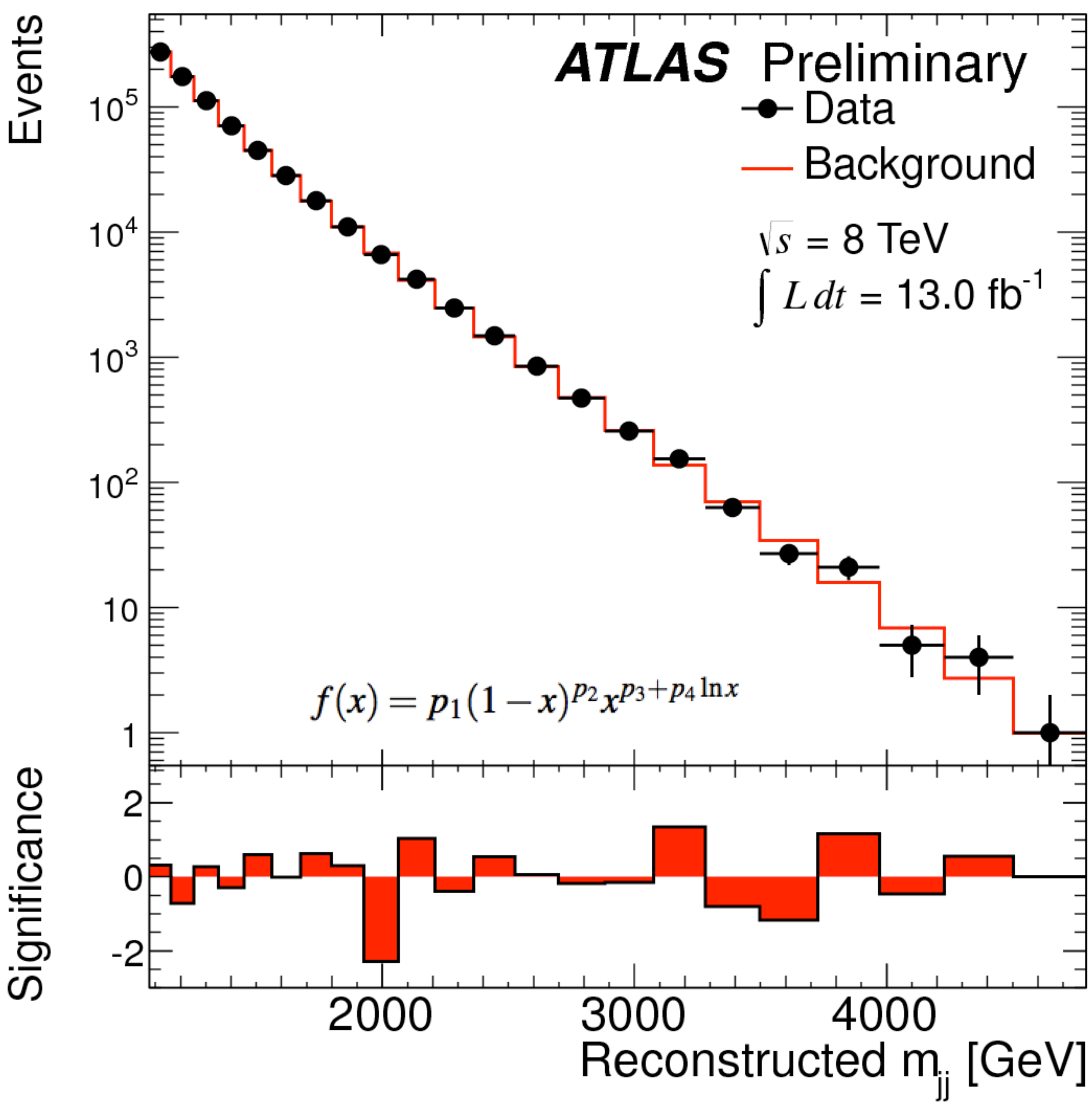


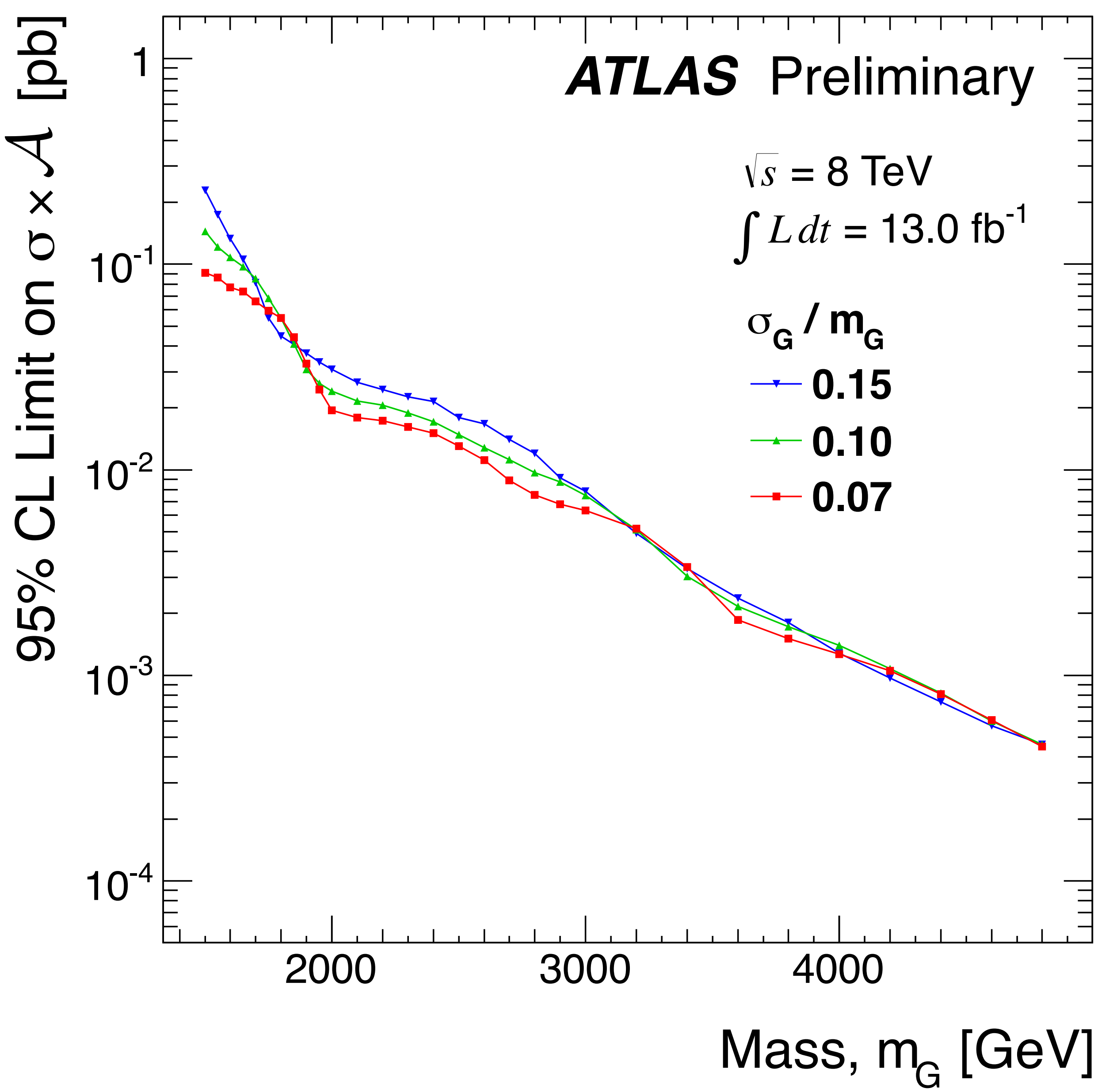
Dijet resonances

BumpHunt on smooth parameterization of dijet mass distribution

Two-body decays to jets are a signature of many models: Z’/W’, excited quarks (qg), diquarks, chiral color, axigluons, black holes, KK gravitons, ...

Example limits: m_{q^*} > 3.84 TeV, $(\text{sigma}^*\text{A})_{\text{Gaussian}}$ <~ 1 fb @ 4 TeV





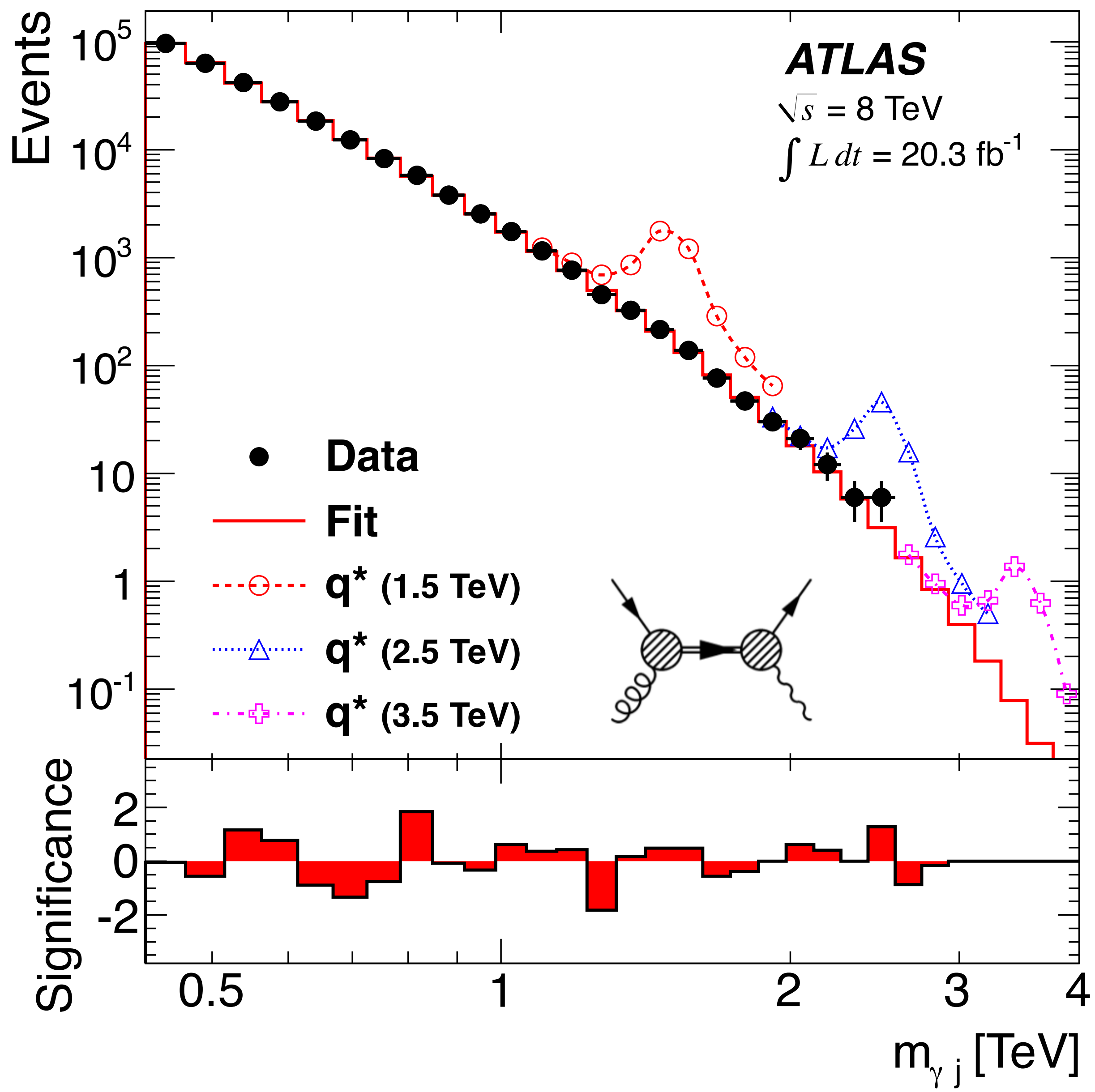
Photon-jet resonances

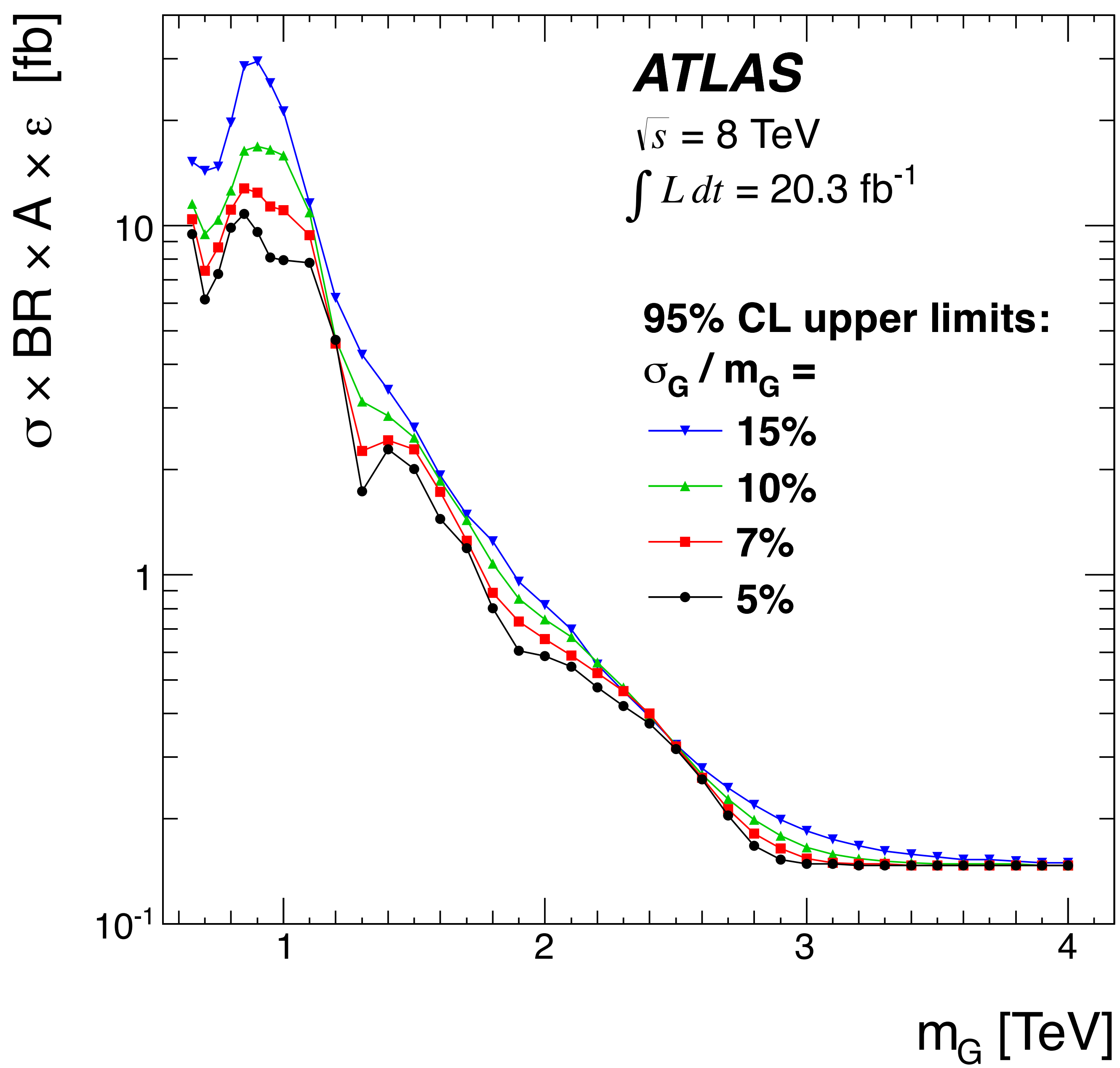
PLB 728, 562 (2013)

Long list of models: quantum black holes, string resonances, quirks, technipions, ...

Counterpart to searches for quark + gluon radiation: quark + photon radiation

Lower trigger thresholds (m_{gj}~300 GeV vs m_{jj}~1 TeV for unprescaled triggers)

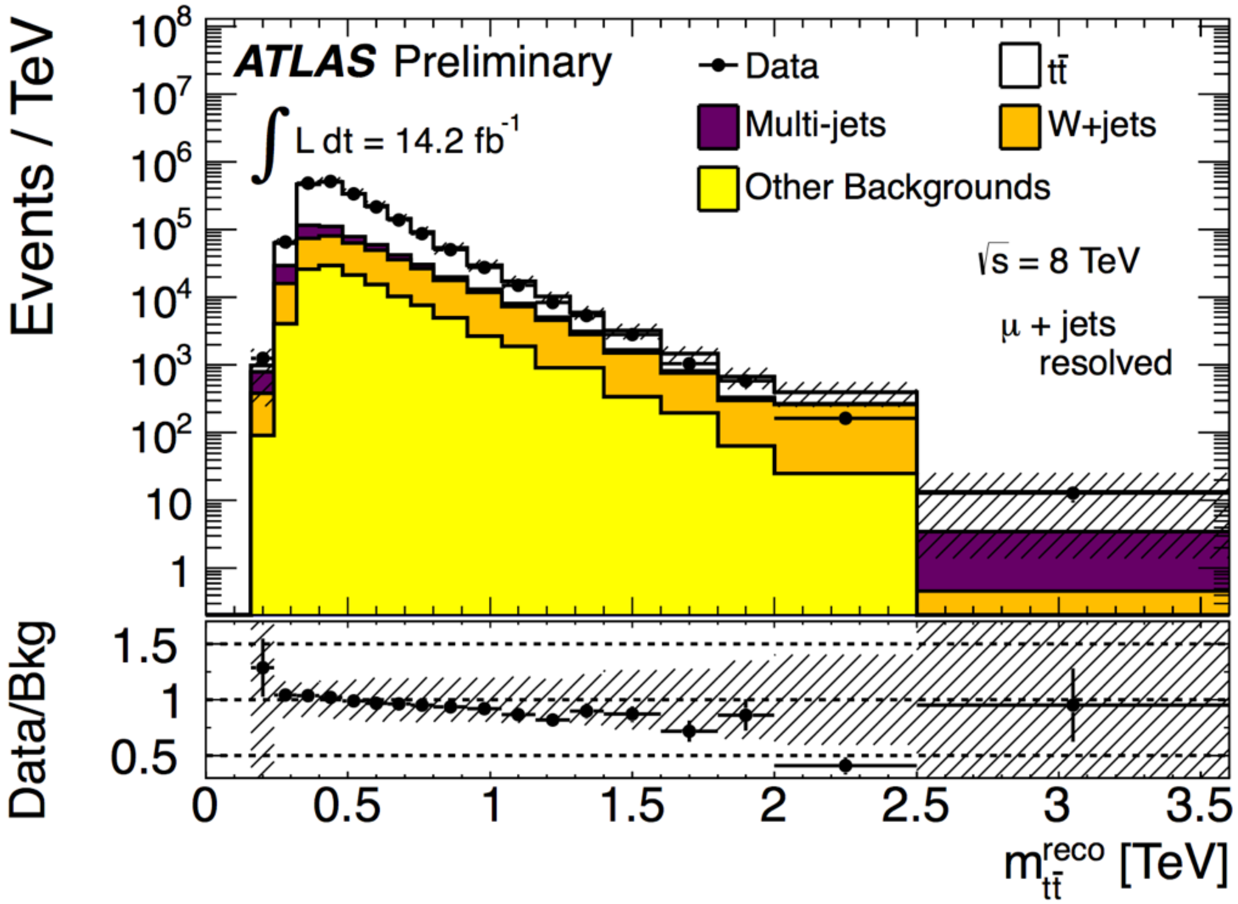


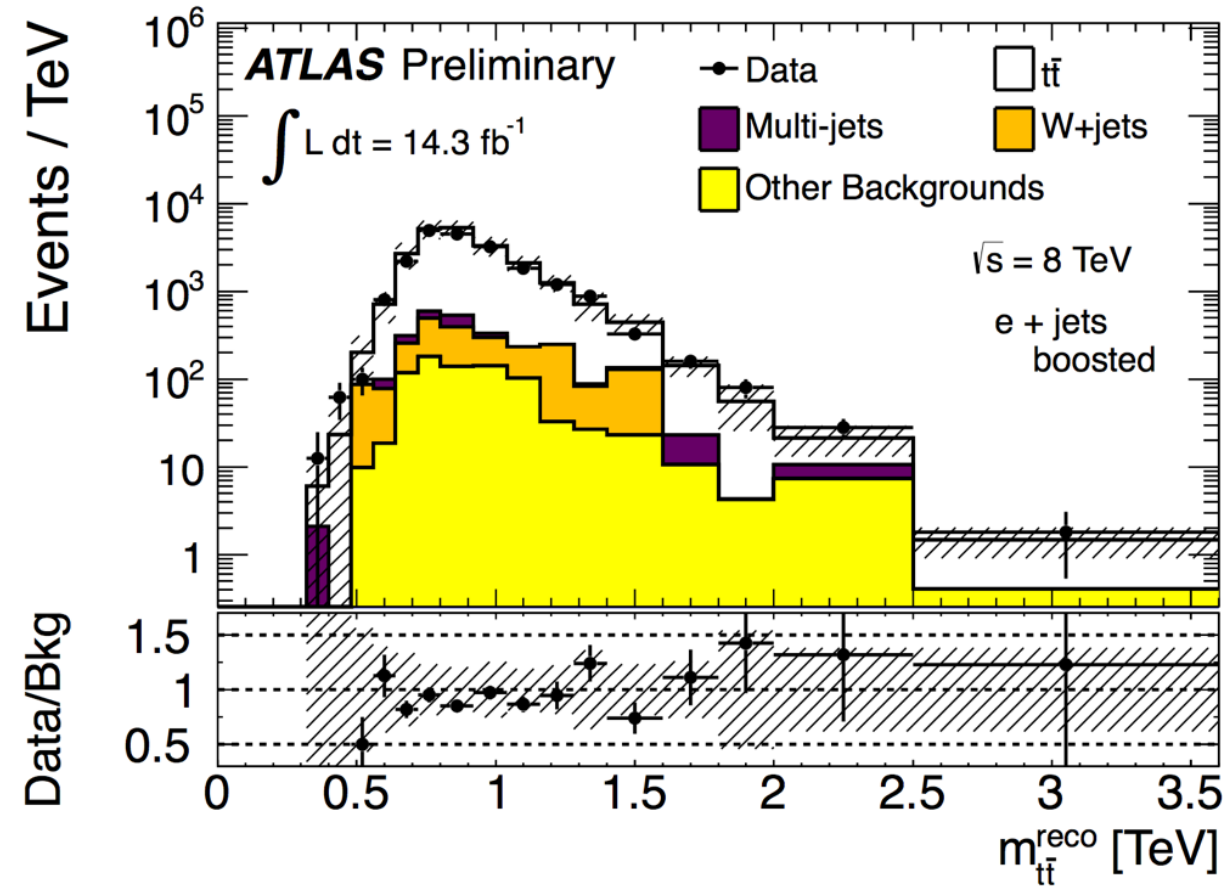


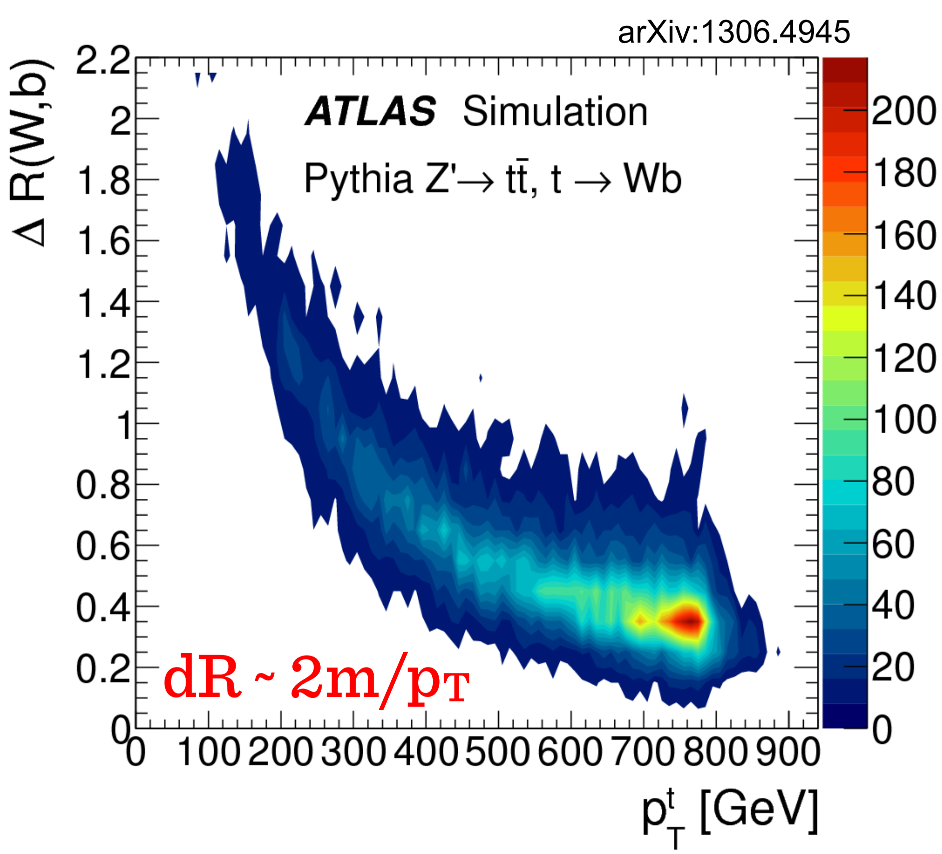
Top pair resonances

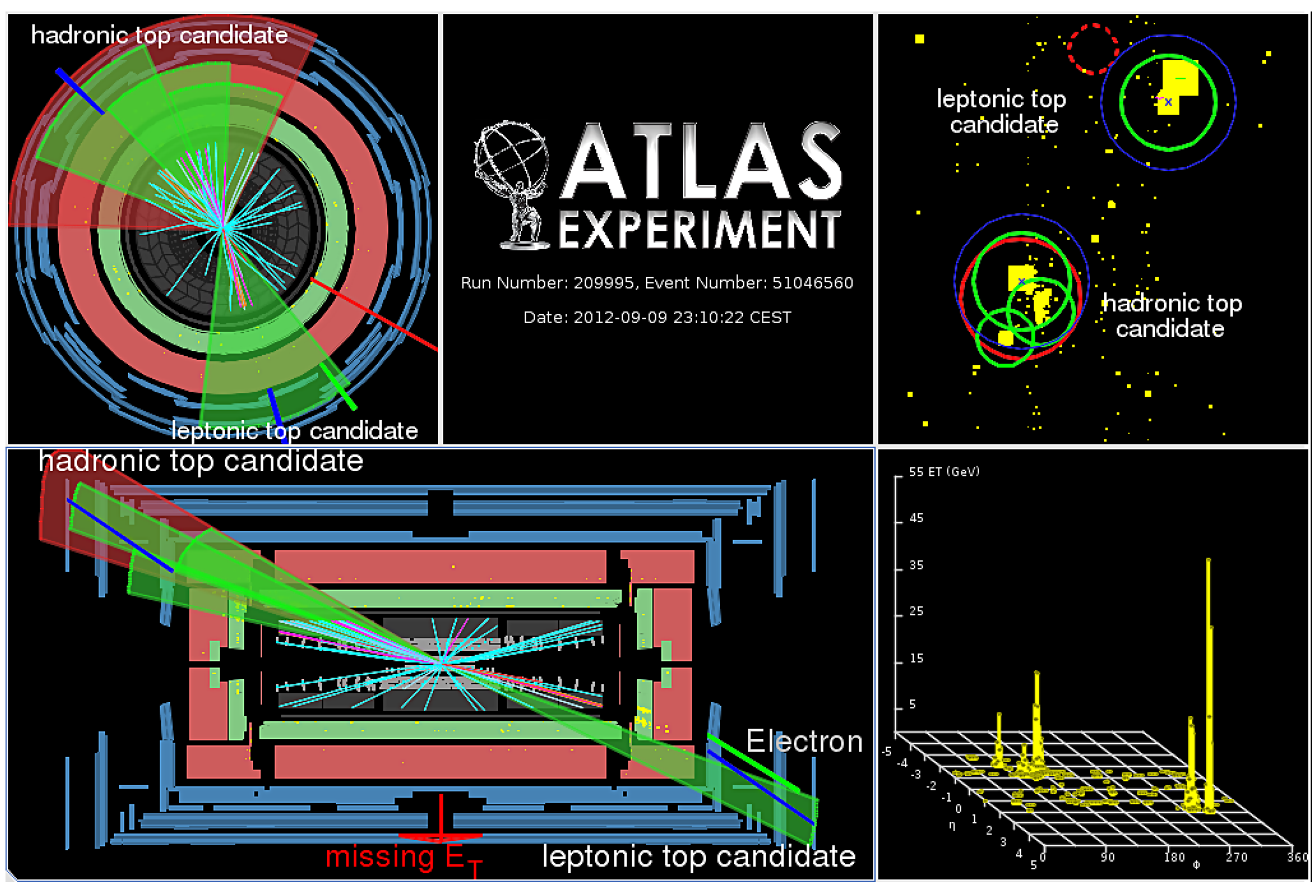
KK gluons, leptophobic topcolor Z', color octets
(2–3 TeV for assumed couplings)

ATLAS-CONF-2013-052









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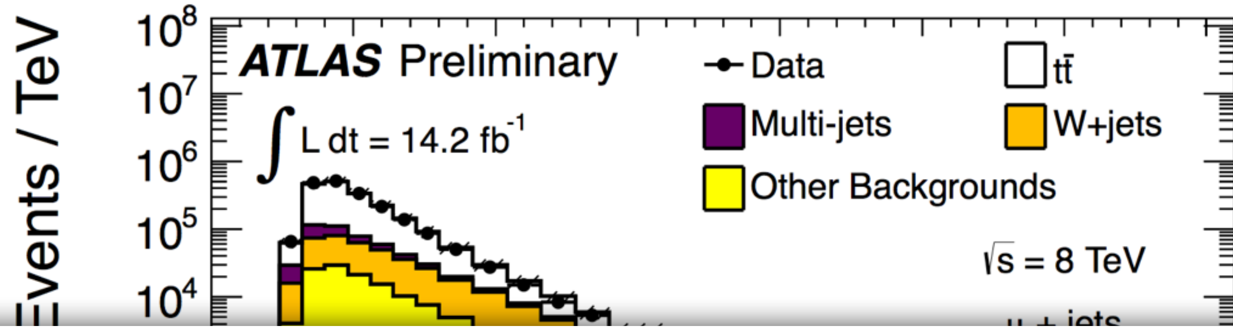
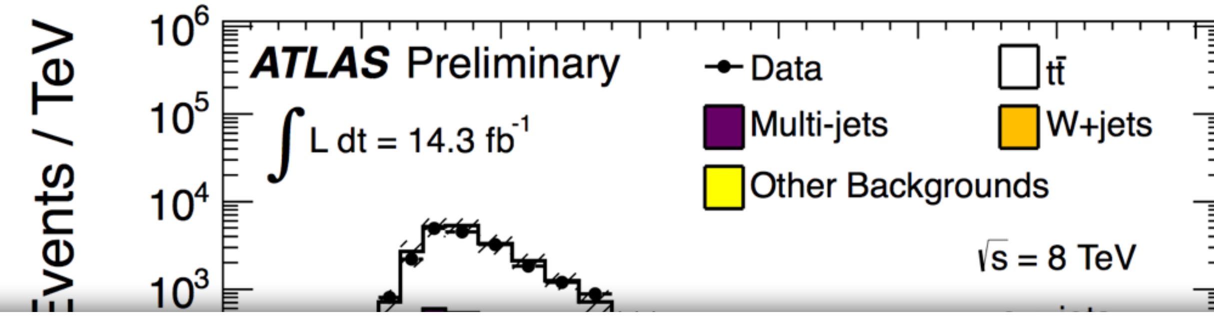
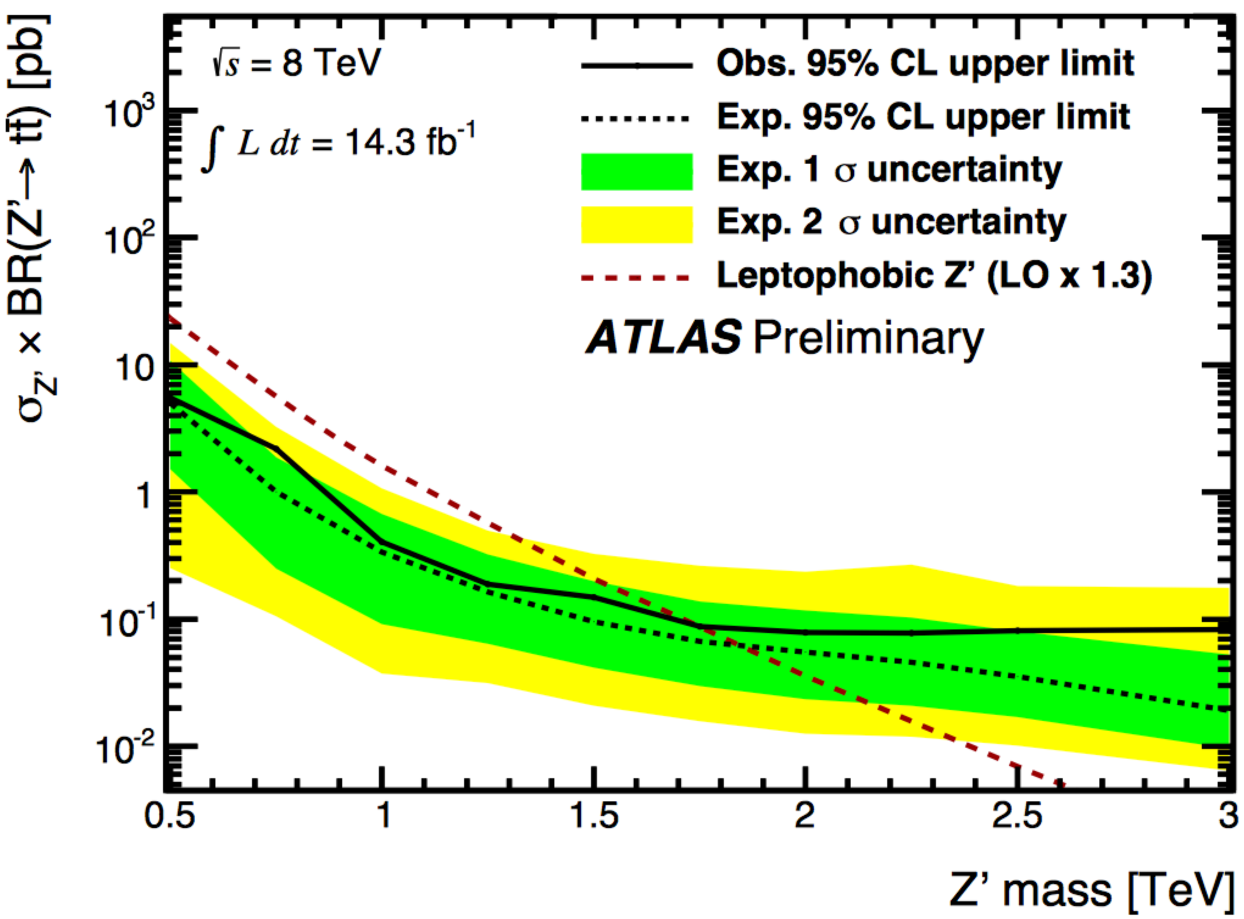
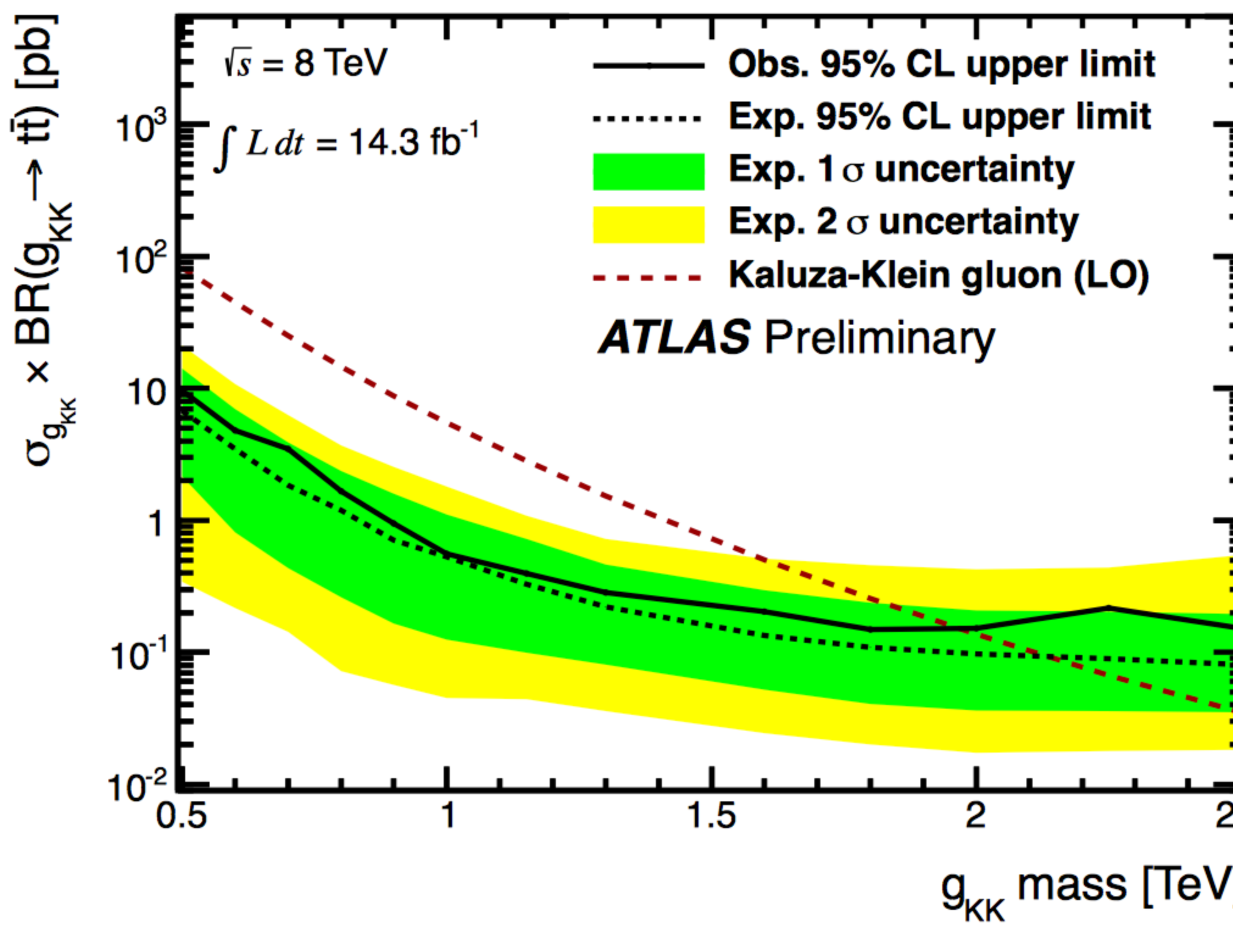
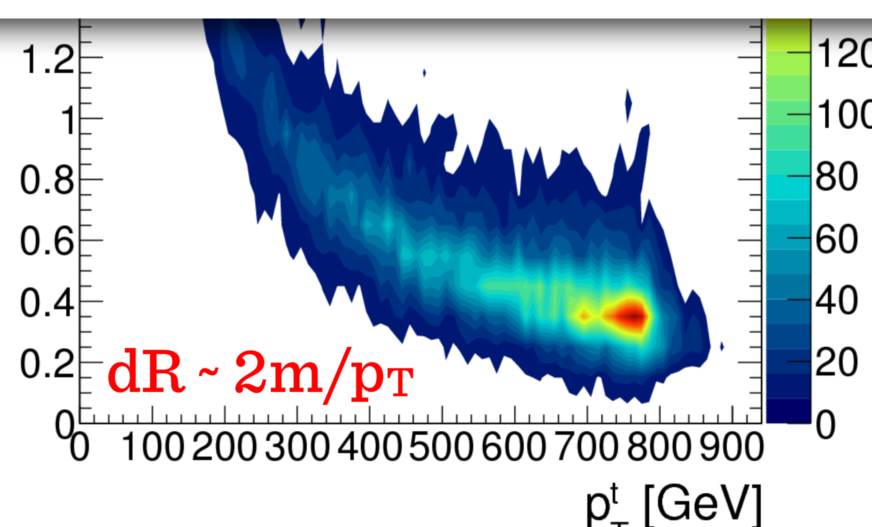
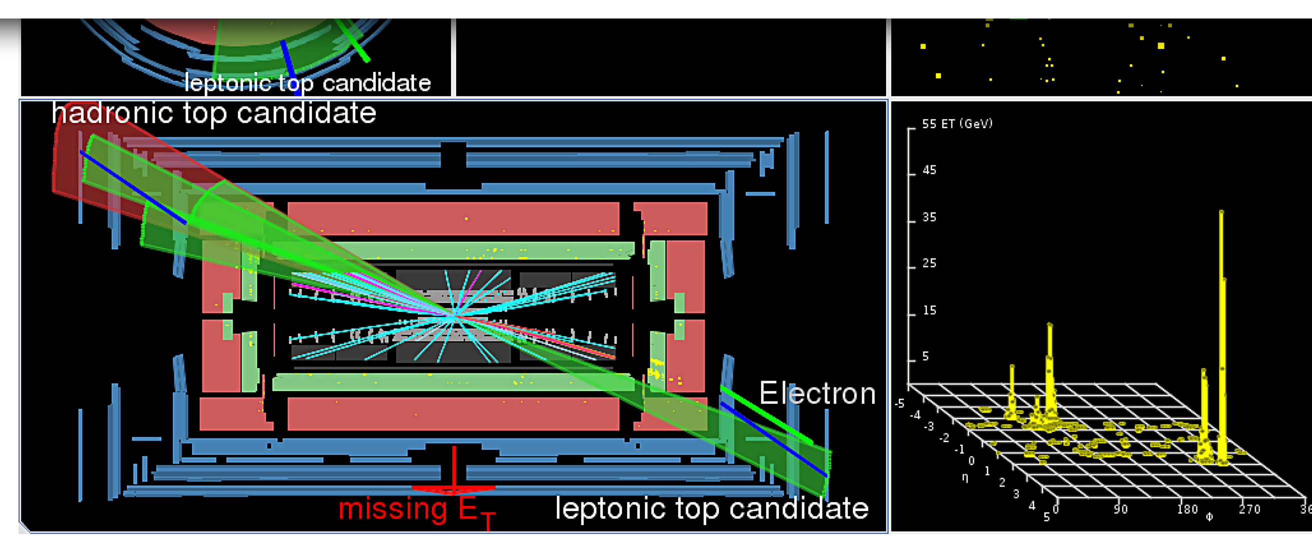






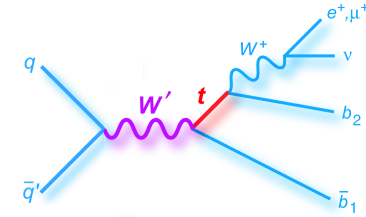






W' -> t b

$$\mathcal{L} = \frac{V'_{ij}}{2\sqrt{2}} \bar{f}_i \gamma_\mu \left(g'_{R_{i,j}}(1+\gamma^5) + g'_{L_{i,j}}(1-\gamma^5) \right) W'^\mu f_j$$



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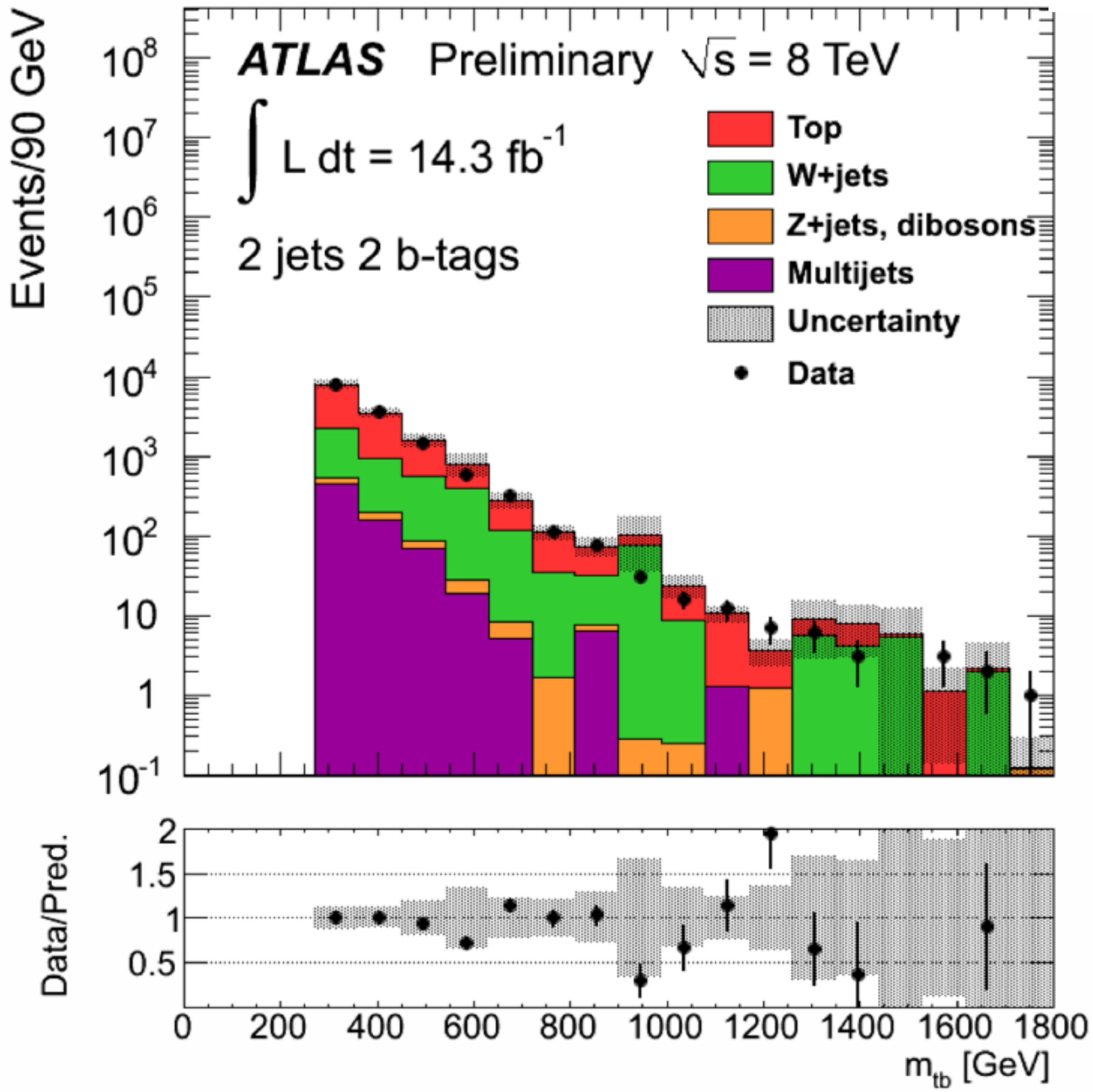
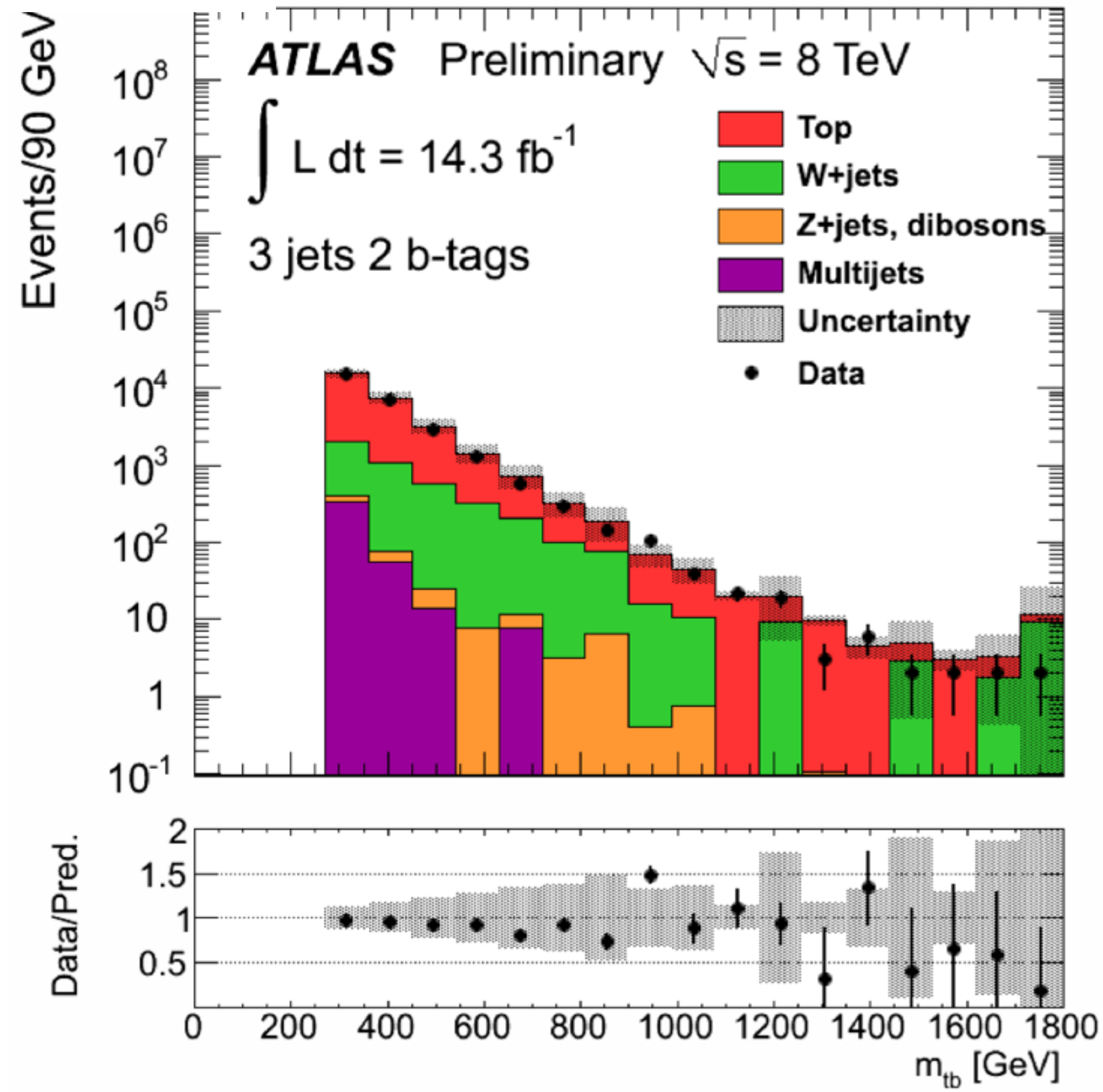
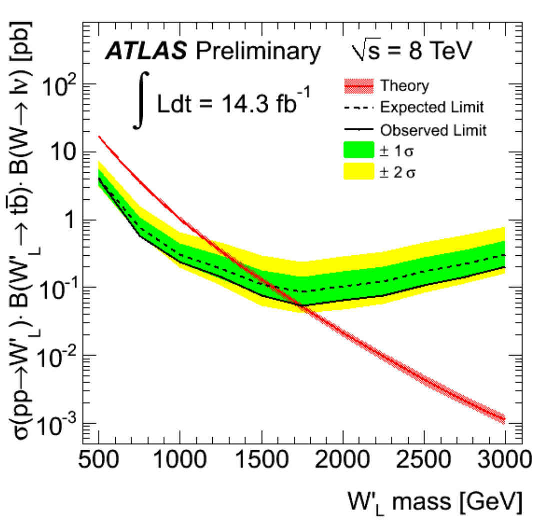
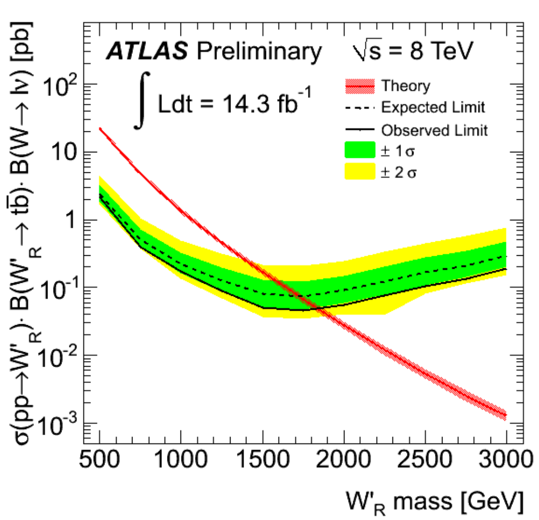
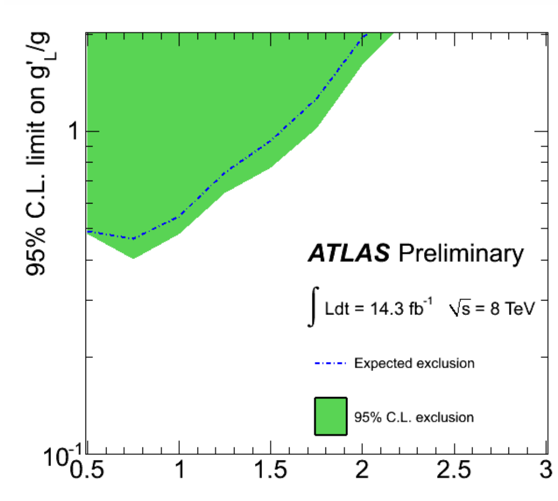
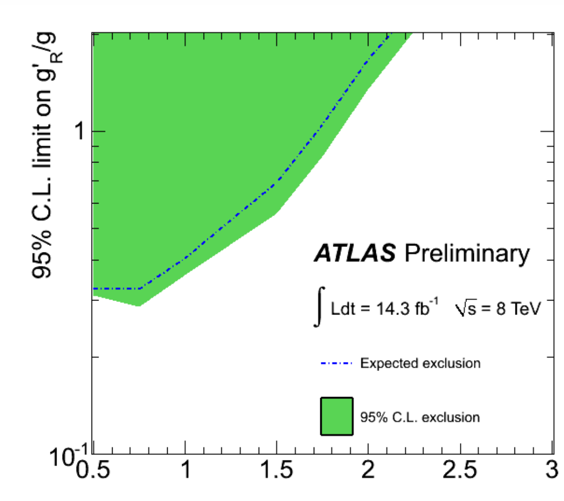






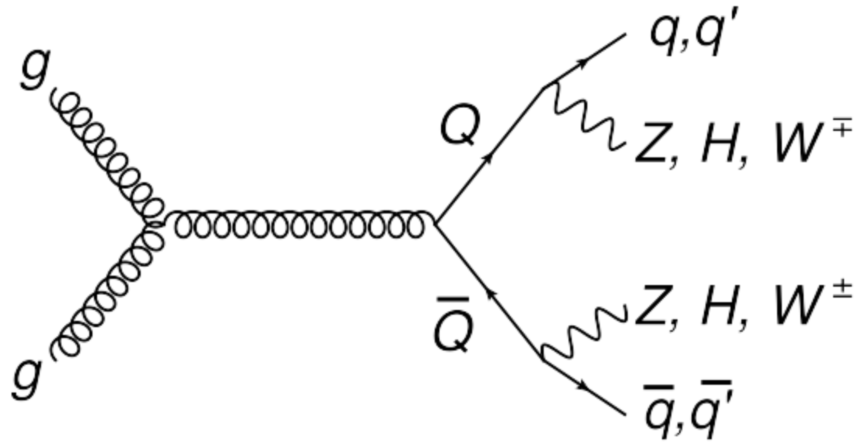




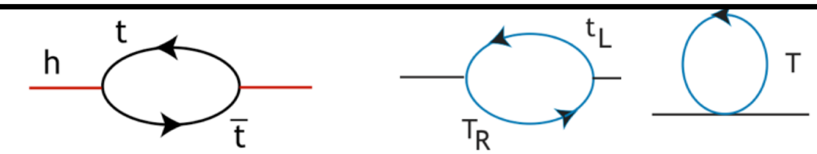


Additional top-like or bottom-like heavy (vector-like) quarks

ATLAS-CONF-2013-060



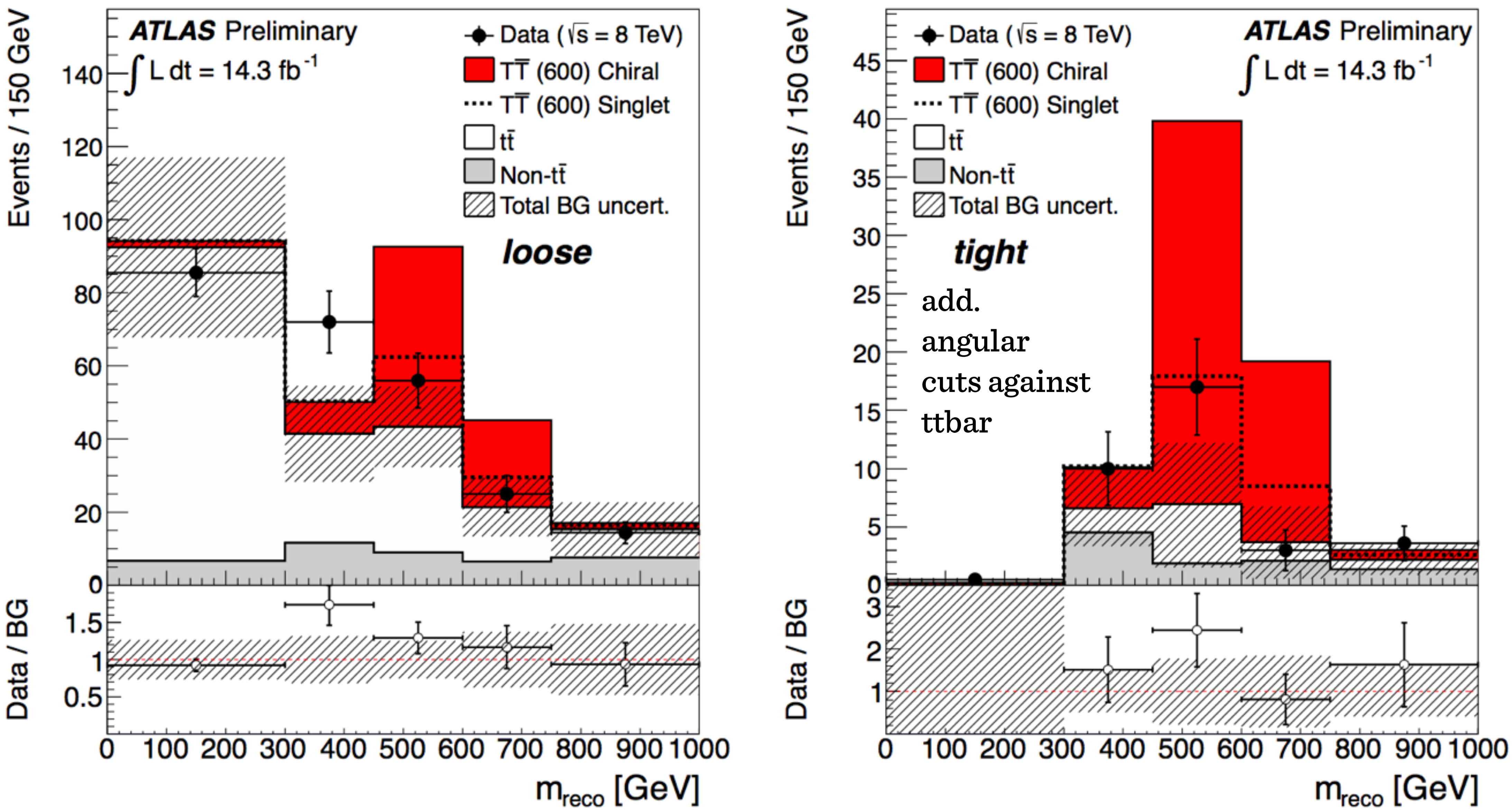
Key to canceling quadratic divergences to Higgs mass in Little Higgs, ED models



$$\Delta\mu^2 = -\frac{3\lambda_t^2}{8\pi}\Lambda^2 \quad \rightarrow \quad \Delta\mu^2 = -\frac{3\lambda_t^2}{8\pi}m_T^2 \log\frac{\Lambda^2}{m_T^2}$$

"Littlest Higgs" model

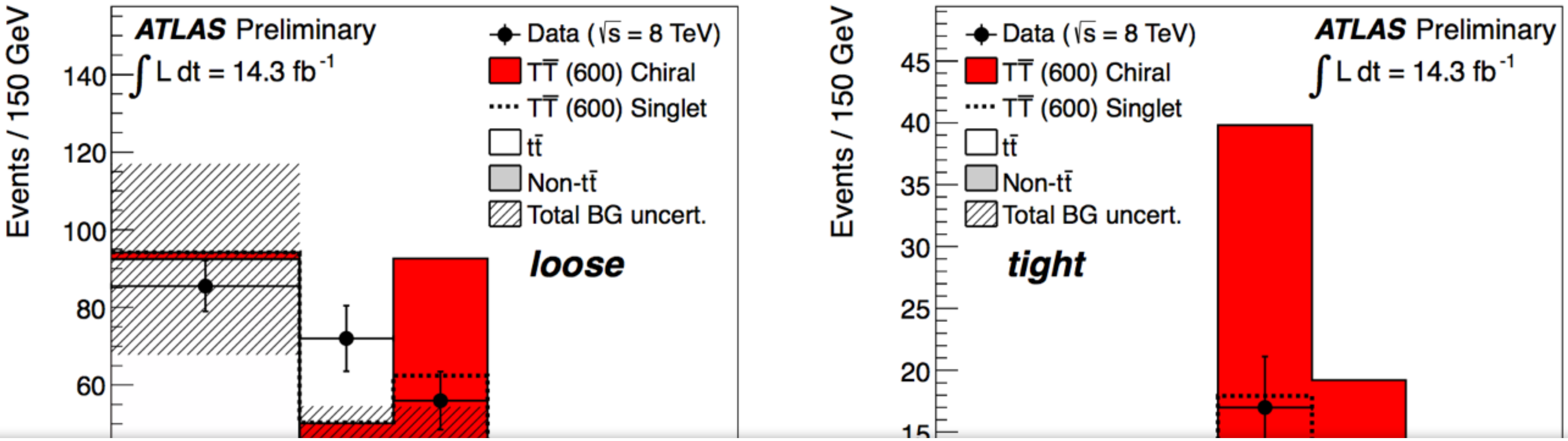
If this set of contributions dominates, the model explains electroweak symmetry breaking. M. Peskin, others

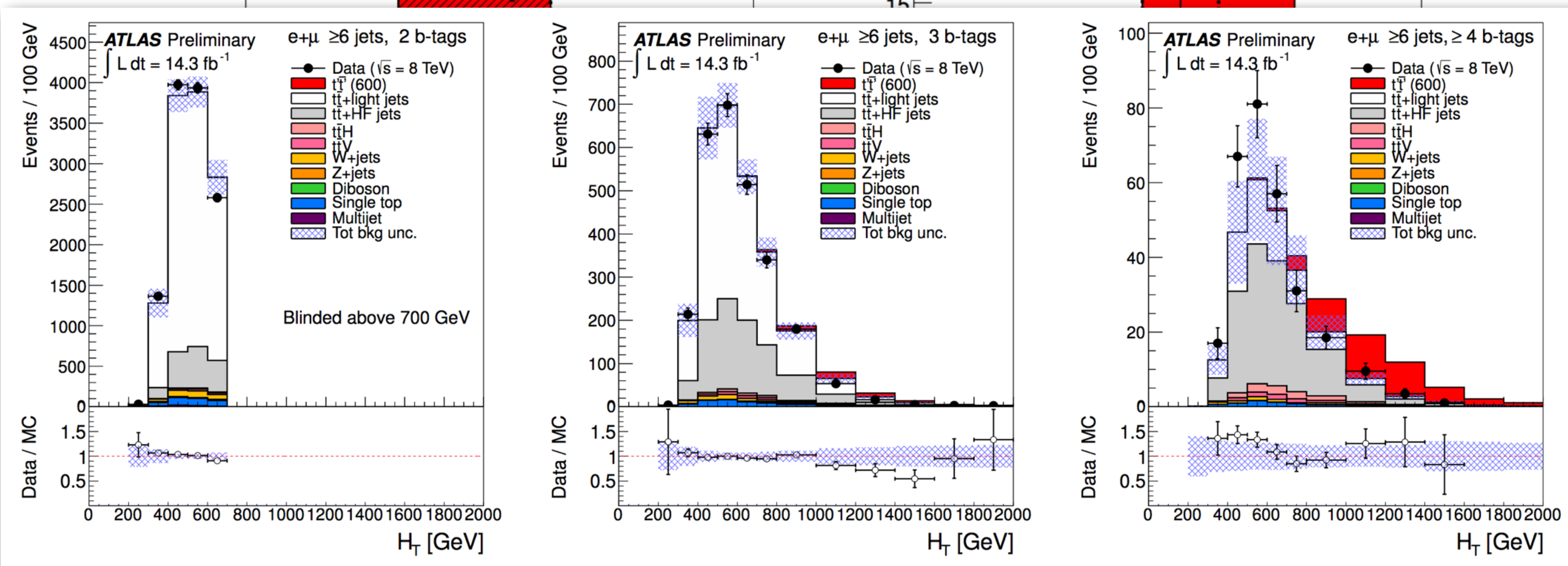


T->Wb

Additional top-like or bottom-like heavy (vector-like) quarks

ATLAS-CONF-2013-060
ATLAS-CONF-2013-018





TT -> tHtH, tZtH, bWtH

Additional top-like or bottom-like heavy (vector-like) quarks

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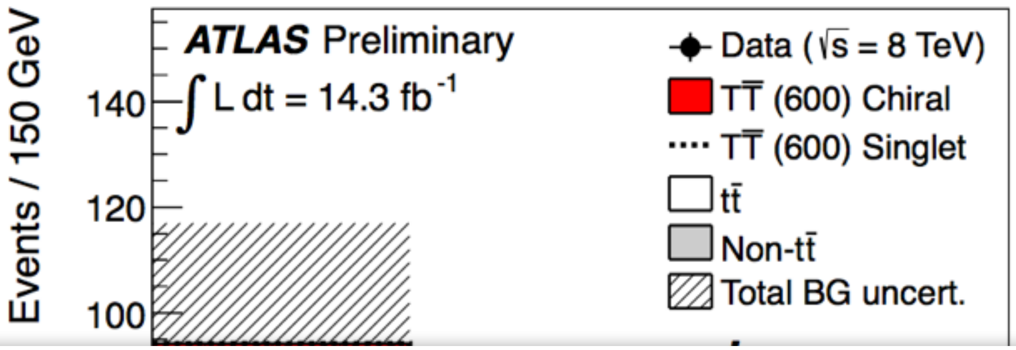
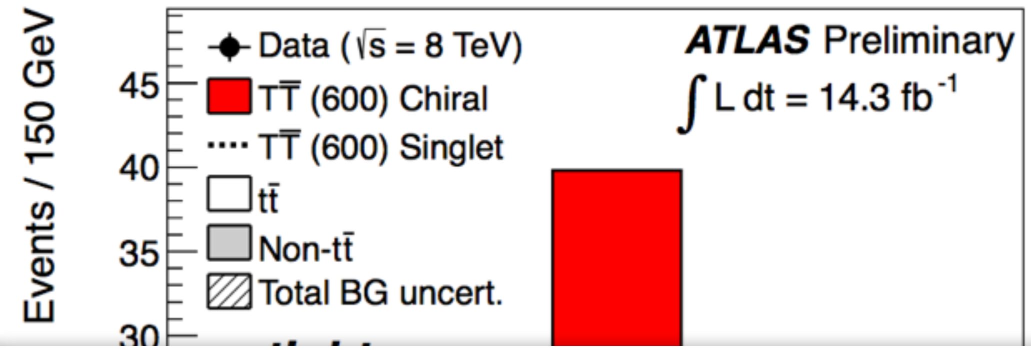
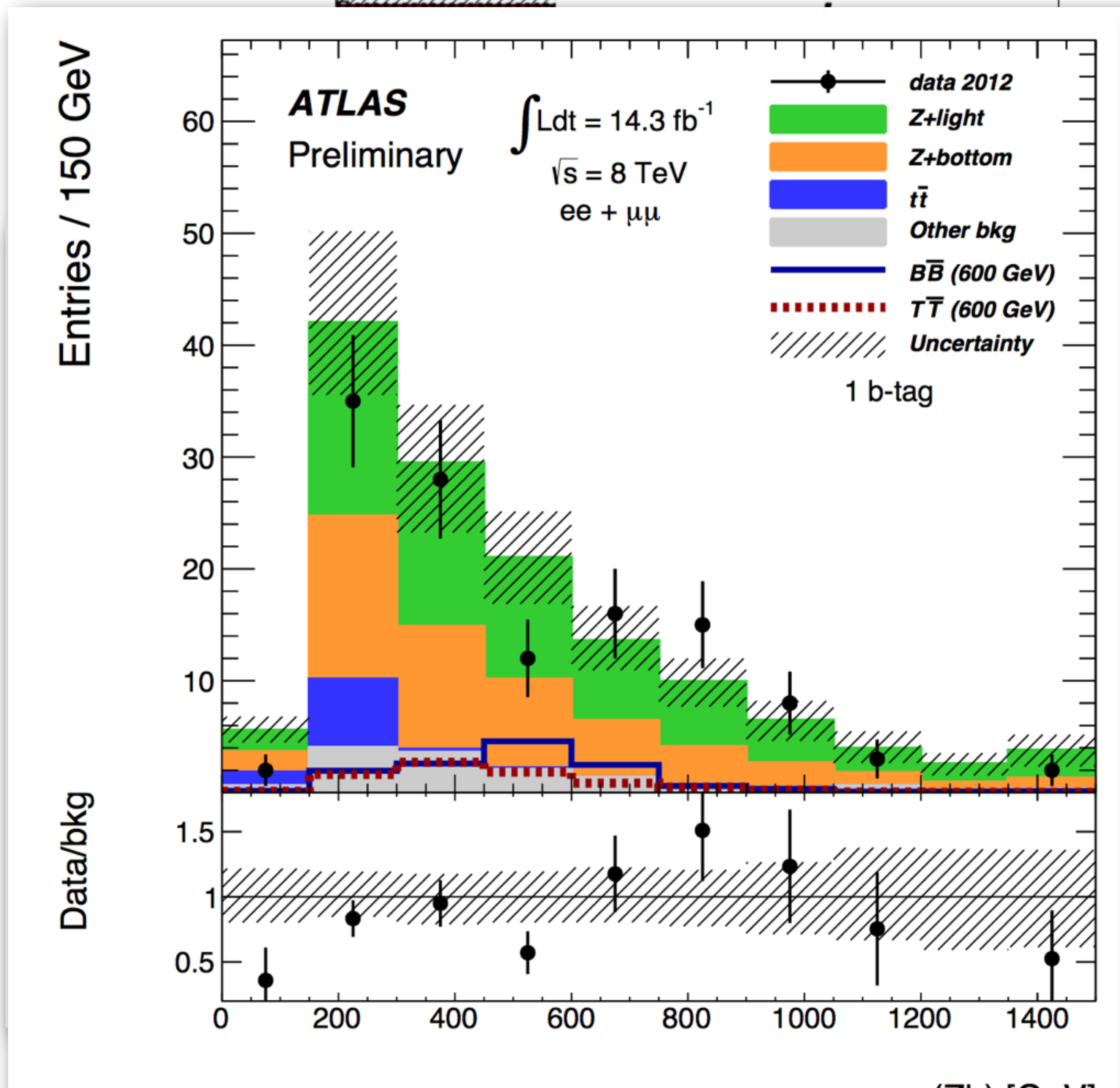
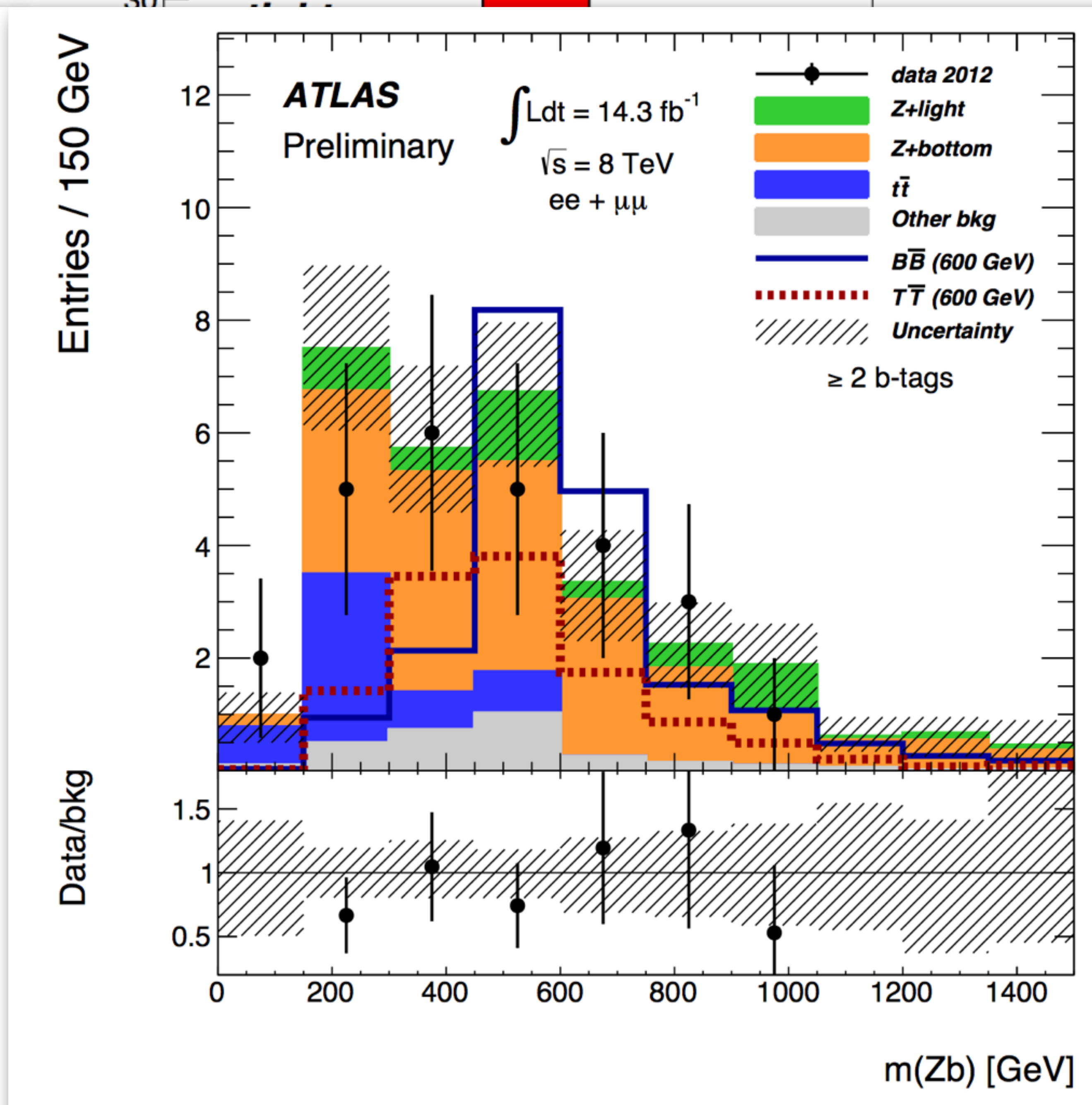
ATLAS-CONF-2013-018

ATLAS-CONF-2013-056





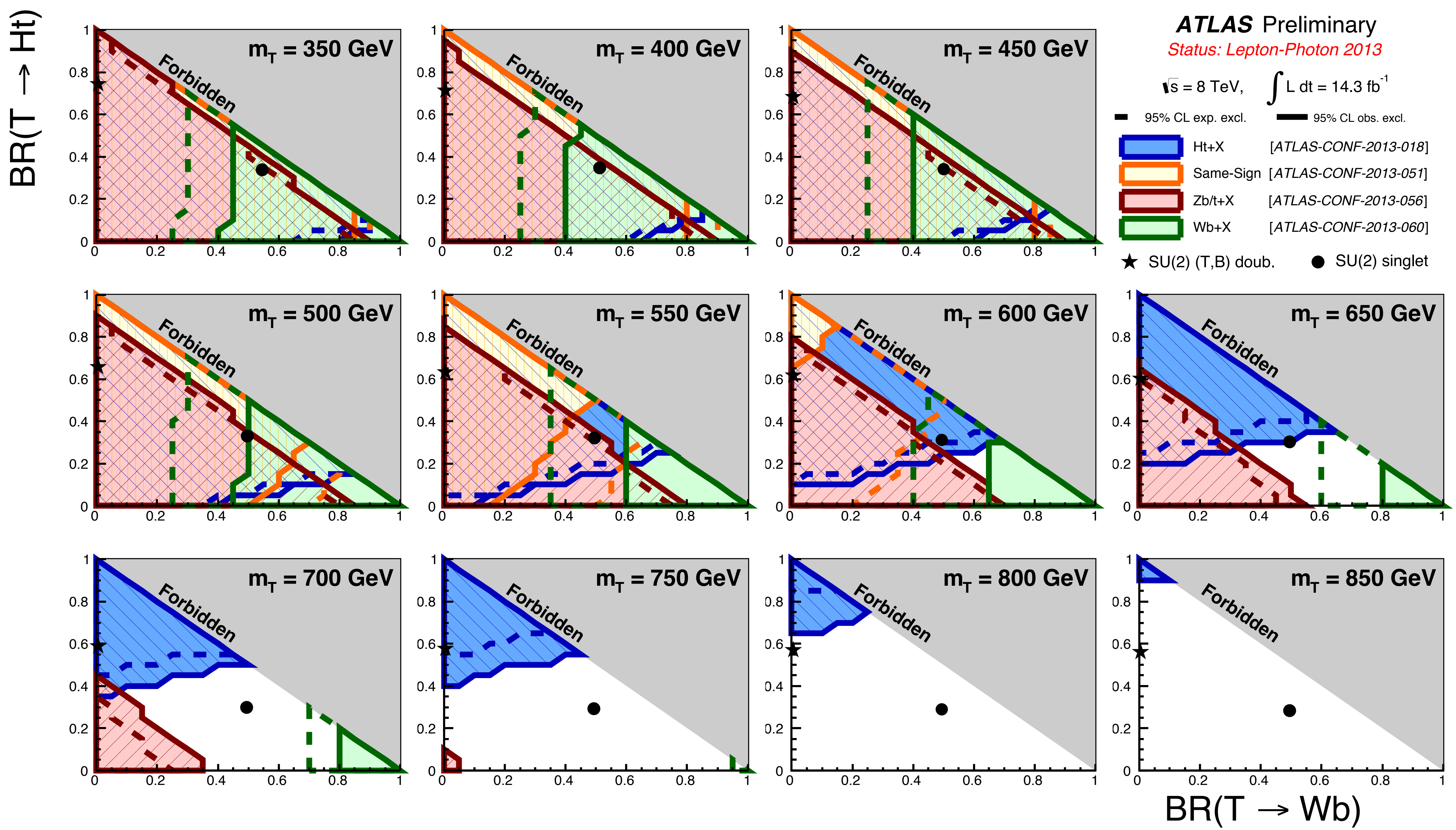




B-> b Z, T -> t Z

Constraints on Vectorlike Quarks

ATLAS-CONF-2013-060
ATLAS-CONF-2013-018
ATLAS-CONF-2013-056



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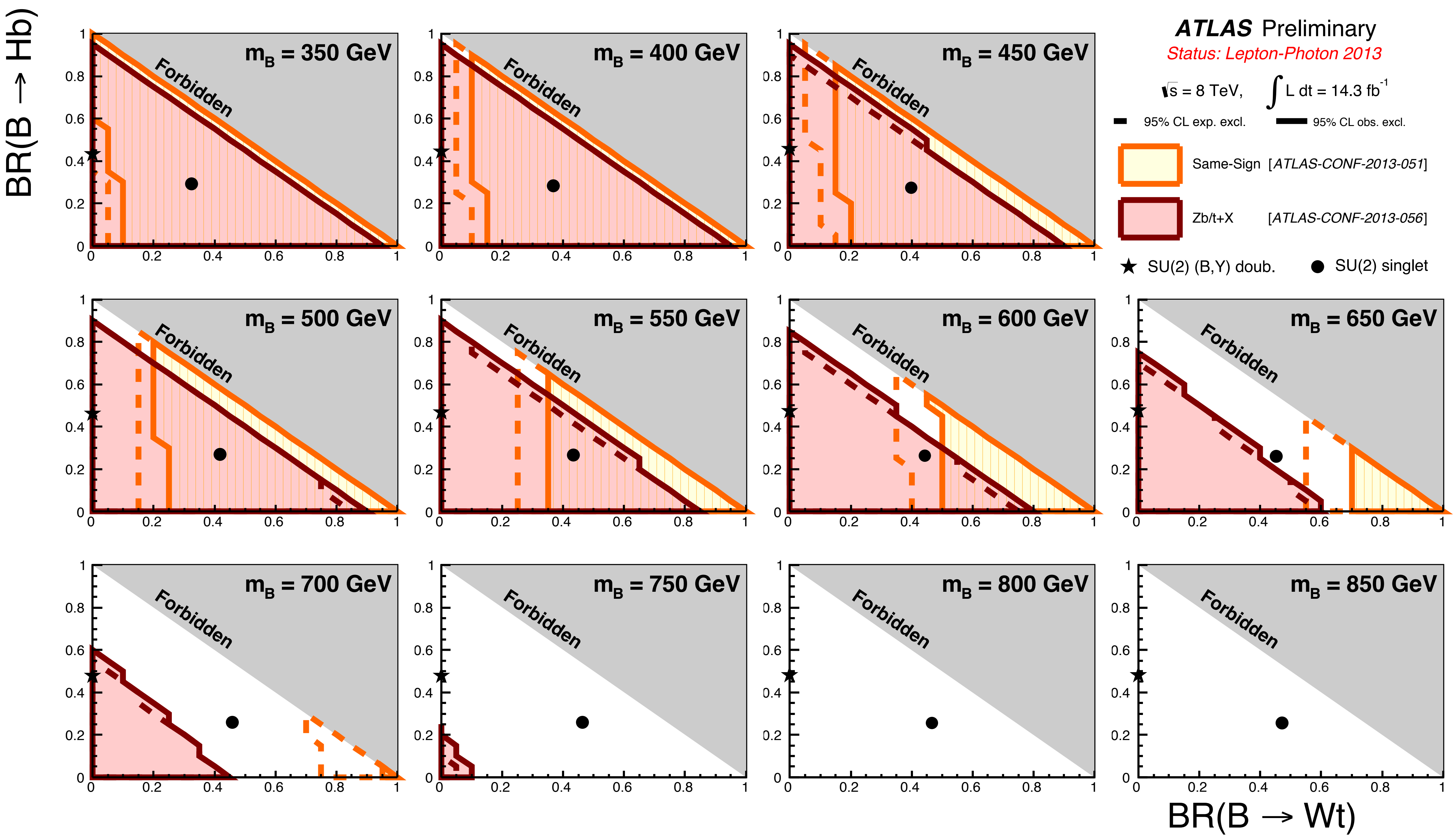
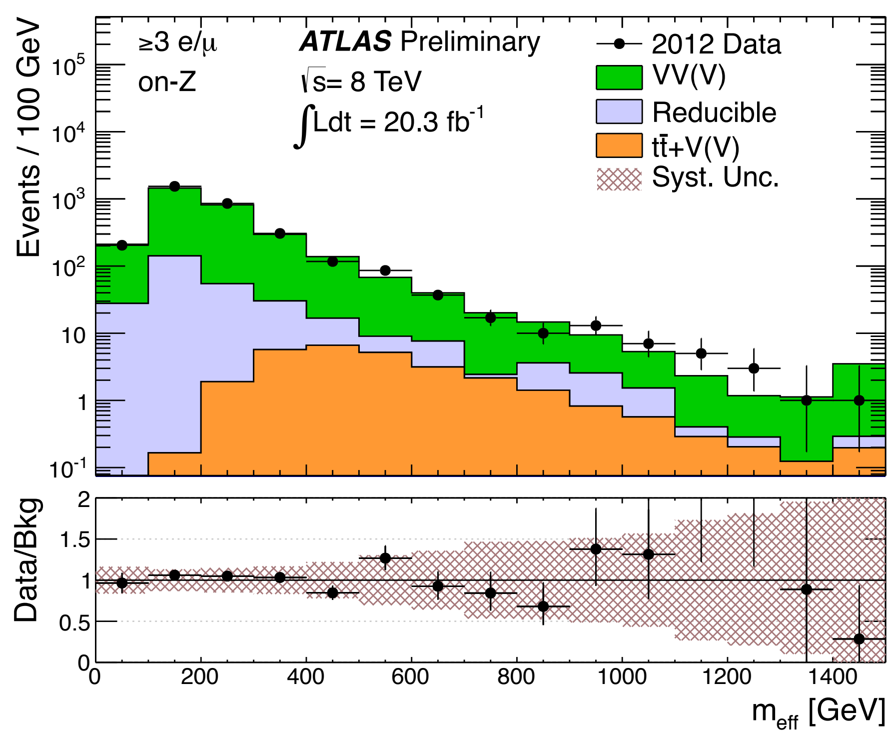
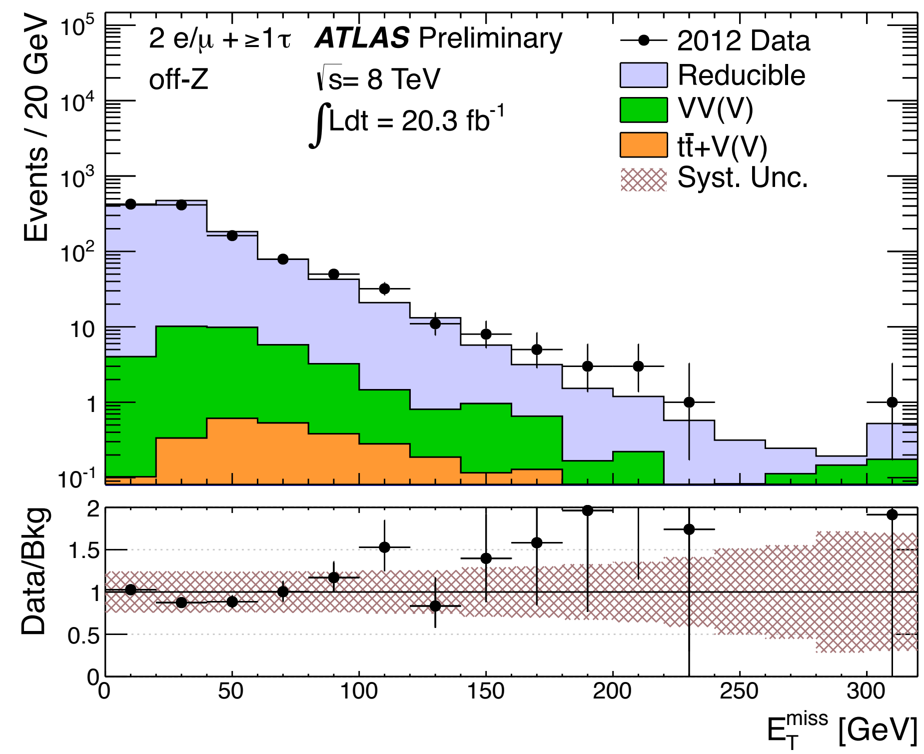


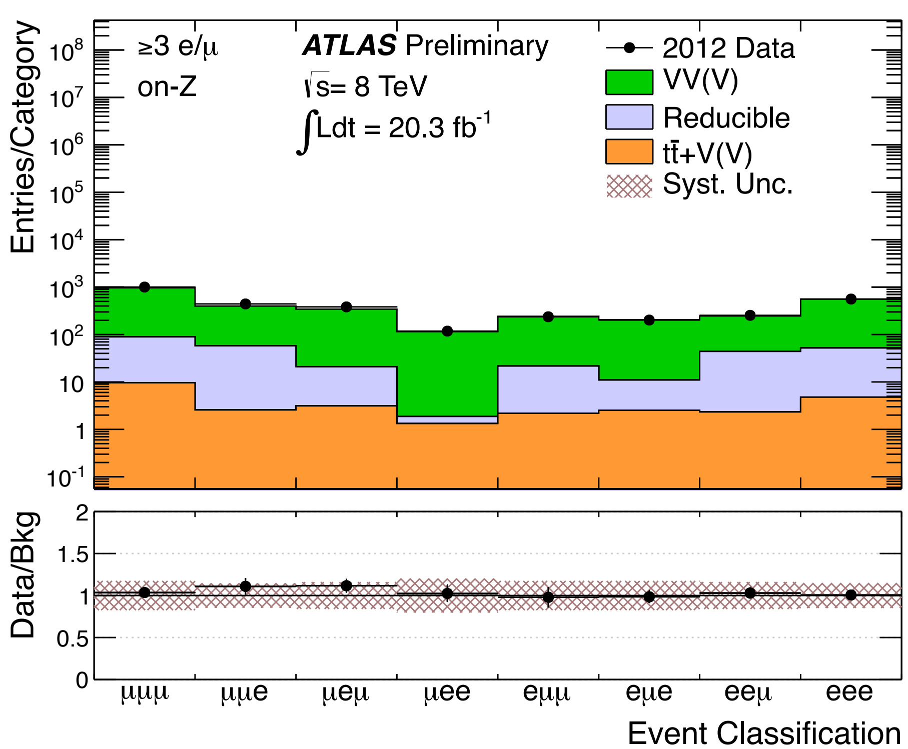
Multilepton Search

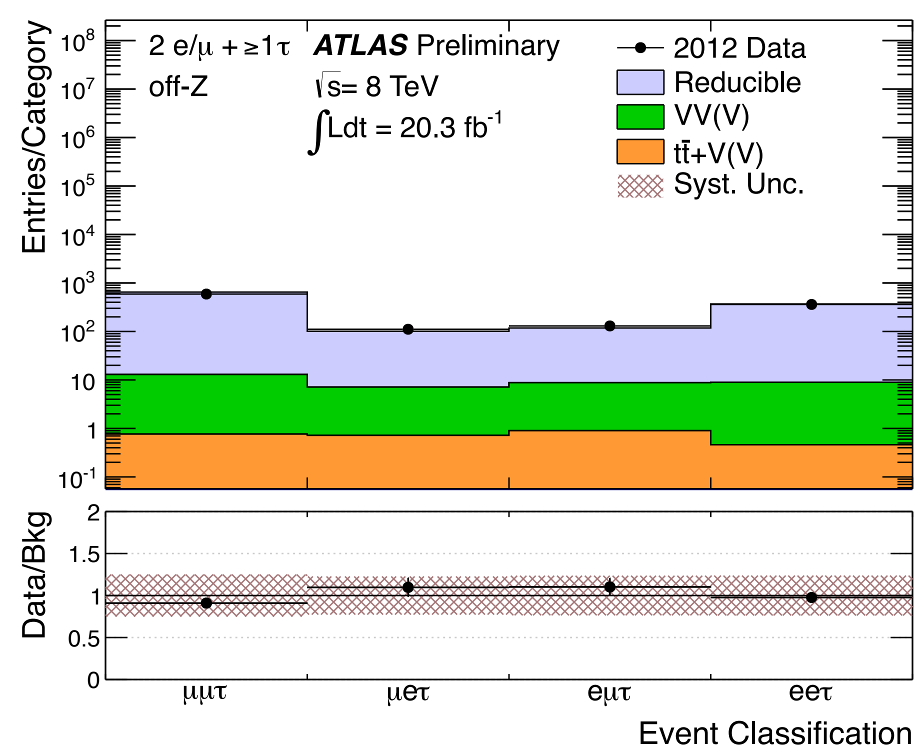
ATLAS-CONF-2013-070

Flavor Chan.	Z Chan.	Expected	Observed
$\geq 3e/\mu$	off-Z	$260 \pm 10 \pm 40$	280
$2e/\mu + \geq 1\tau_{\mathrm{had}}$	off-Z	$1200 \pm 10 \pm 290$	1193
$\geq 3e/\mu$	on-Z	$3100 \pm 40 \pm 500$	3199
$2e/\mu + \geq 1\tau_{\mathrm{had}}$	on-Z	$17000 \pm 40 \pm 4000$	14733









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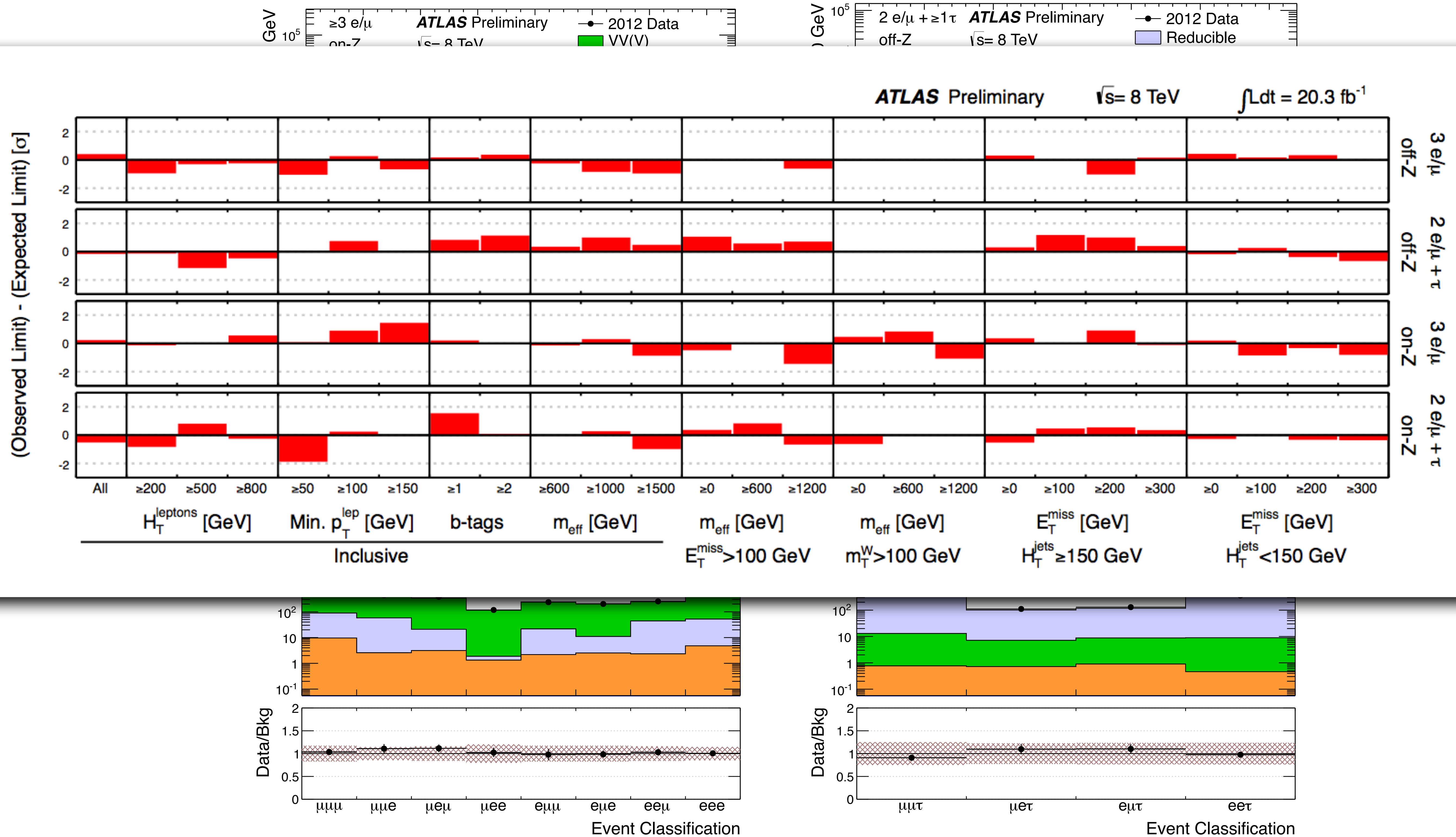
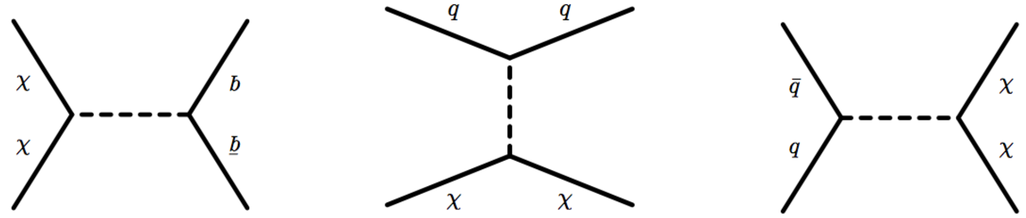


Mono-X Searches

ATLAS-CONF-2012-147

Assume:

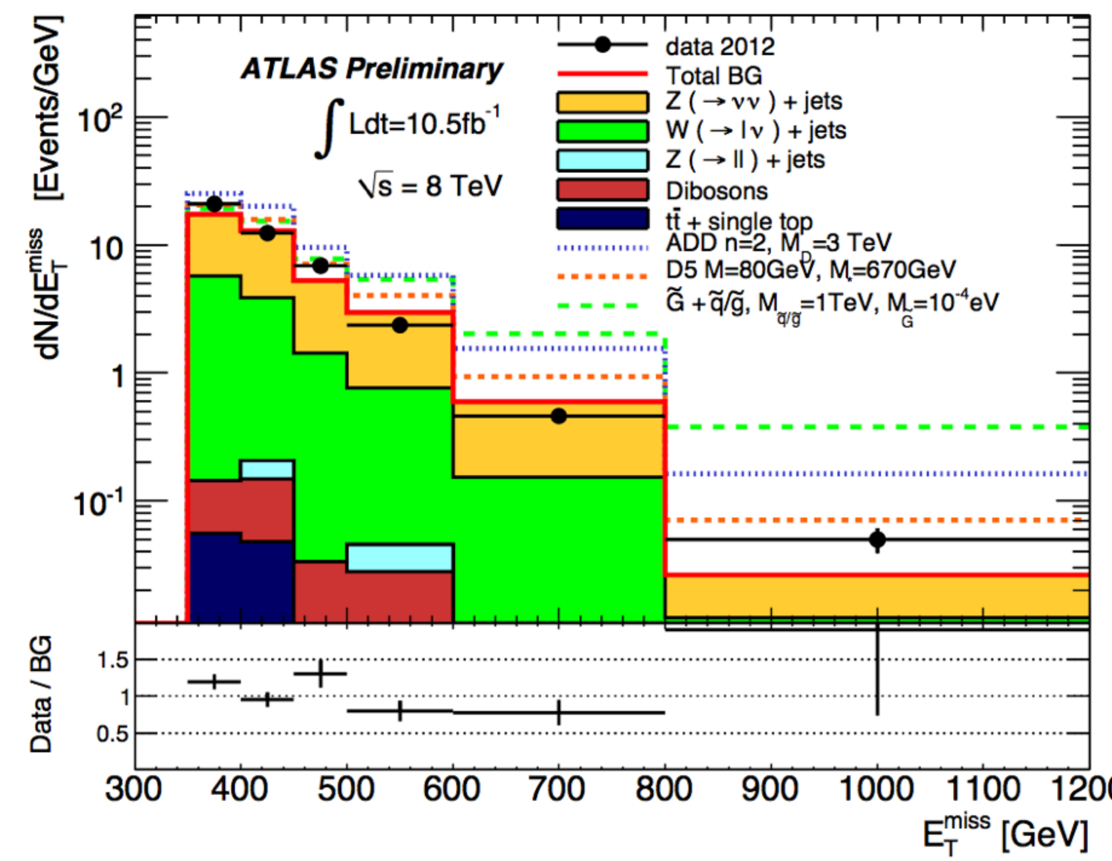


Indirect detection | Direct detection | Collider searches

Effective theory with only two parameters (WIMP mass, coupling) and choice of Lorentz structure

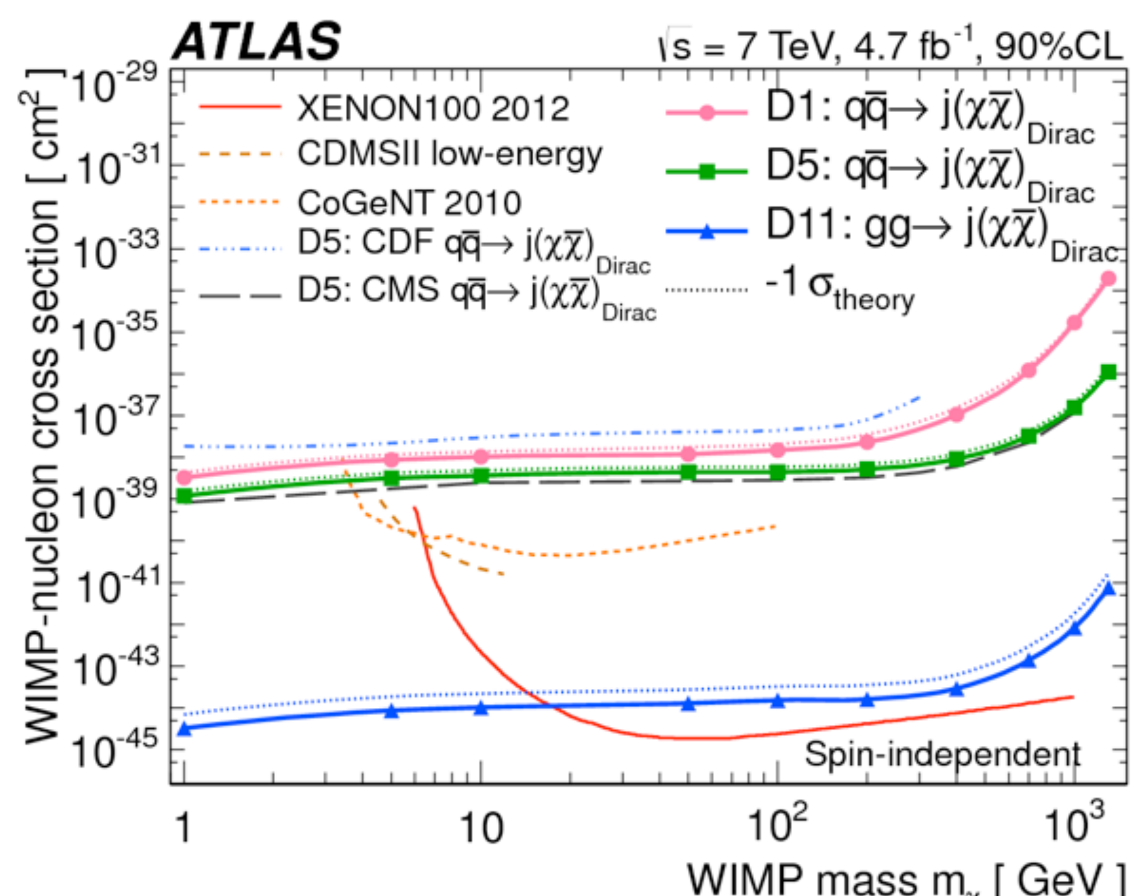
TABLE I. Operators coupling WIMPs to SM particles. The operator names beginning with D, C, R apply to WIMPS that are Dirac fermions, complex scalars or real scalars, respectively.

Name	Operator	Coefficient
D1	$\bar{\chi}\chi\bar{q}q$	m_q/M_*^3
D2	$\bar{\chi}\gamma^5\chi\bar{q}q$	im_q/M_*^3
D3	$\bar{\chi}\chi\bar{q}\gamma^5 q$	im_q/M_*^3
D4	$\bar{\chi}\gamma^5\chi\bar{q}\gamma^5 q$	m_q/M_*^3
D5	$\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu q$	$1/M_*^2$
D6	$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu q$	$1/M_*^2$
D7	$\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu\gamma^5 q$	$1/M_*^2$
D8	$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu\gamma^5 q$	$1/M_*^2$
D9	$\bar{\chi}\sigma^{\mu\nu}\chi\bar{q}\sigma_{\mu\nu}q$	$1/M_*^2$
D10	$\bar{\chi}\sigma_{\mu\nu}\gamma^5\chi\bar{q}\sigma_{\alpha\beta}q$	i/M_*^2
D11	$\bar{\chi}\chi G_{\mu\nu}G^{\mu\nu}$	$\alpha_s/4M_*^3$
D12	$\bar{\chi}\gamma^5\chi G_{\mu\nu}G^{\mu\nu}$	$i\alpha_s/4M_*^3$
D13	$\bar{\chi}\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$i\alpha_s/4M_*^3$
D14	$\bar{\chi}\gamma^5\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$\alpha_s/4M_*^3$
C1	$\chi^\dagger\chi\bar{q}q$	m_q/M_*^2
C2	$\chi^\dagger\chi\bar{q}\gamma^5 q$	im_q/M_*^2
C3	$\chi^\dagger\partial_\mu\chi\bar{q}\gamma^\mu q$	$1/M_*^2$
C4	$\chi^\dagger\partial_\mu\chi\bar{q}\gamma^\mu\gamma^5 q$	$1/M_*^2$
C5	$\chi^\dagger\chi G_{\mu\nu}G^{\mu\nu}$	$\alpha_s/4M_*^2$
C6	$\chi^\dagger\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$i\alpha_s/4M_*^2$
R1	$\chi^2\bar{q}q$	$m_q/2M_*^2$
R2	$\chi^2\bar{q}\gamma^5 q$	$im_q/2M_*^2$
R3	$\chi^2 G_{\mu\nu}G^{\mu\nu}$	$\alpha_s/8M_*^2$
R4	$\chi^2 G_{\mu\nu}\tilde{G}^{\mu\nu}$	$i\alpha_s/8M_*^2$



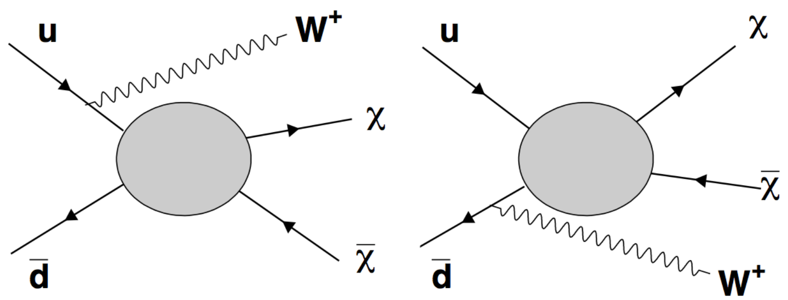
$$\sigma_0^{\rm D5,C3} = 1.38\times10^{-37}\ {\rm cm}^2\left(\frac{\mu_\chi}{1\ {\rm GeV}}\right)^2\left(\frac{300\ {\rm GeV}}{M_*}\right)^4$$

Assuming EFT is valid
Qtr < M*/4pi



Mono-W/Z (hadronic)

PRL 112, 041802 (2014)



Interference can boost W and enhance WIMP production rate

Tag with single 'fat' jet containing boosted W/Z decay subjets

C/A-jet: R=1.2, pT > 250 GeV, |η| < 1.2

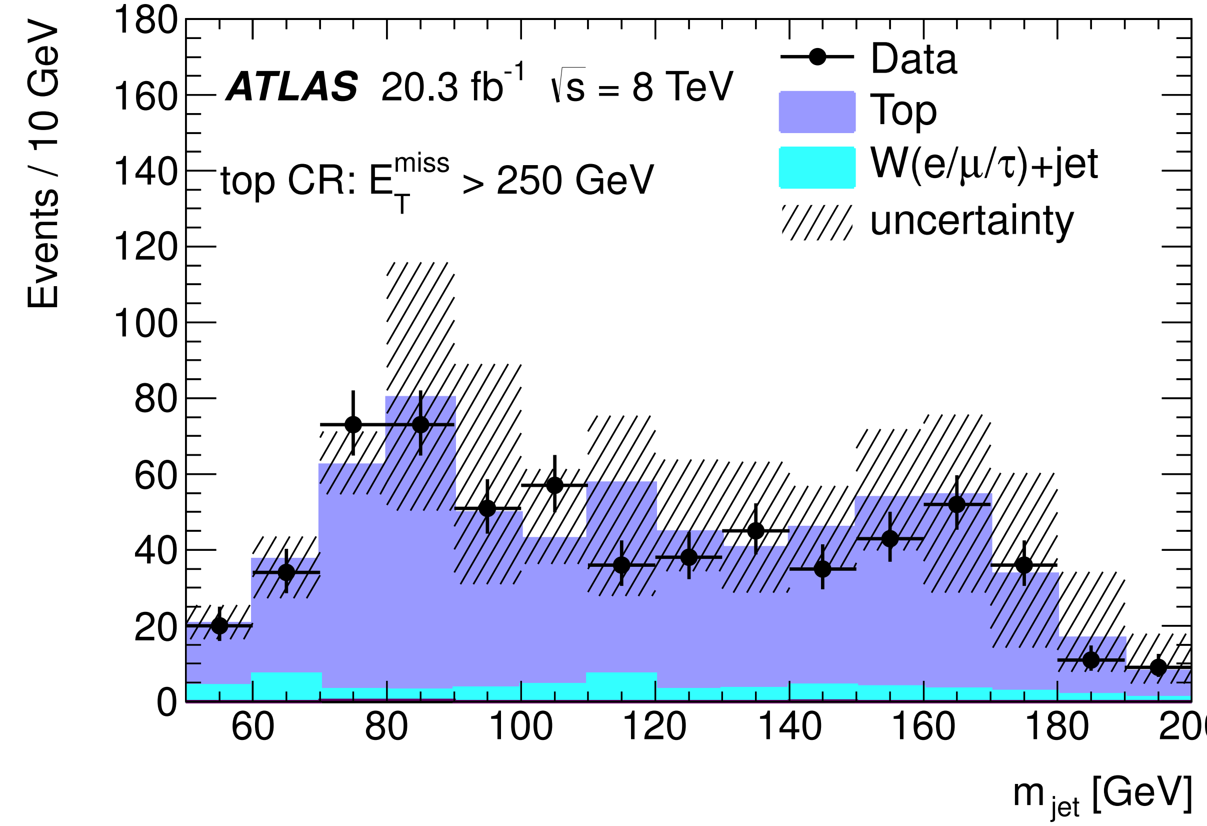
Subjet kinematics consistent with W/Z decay

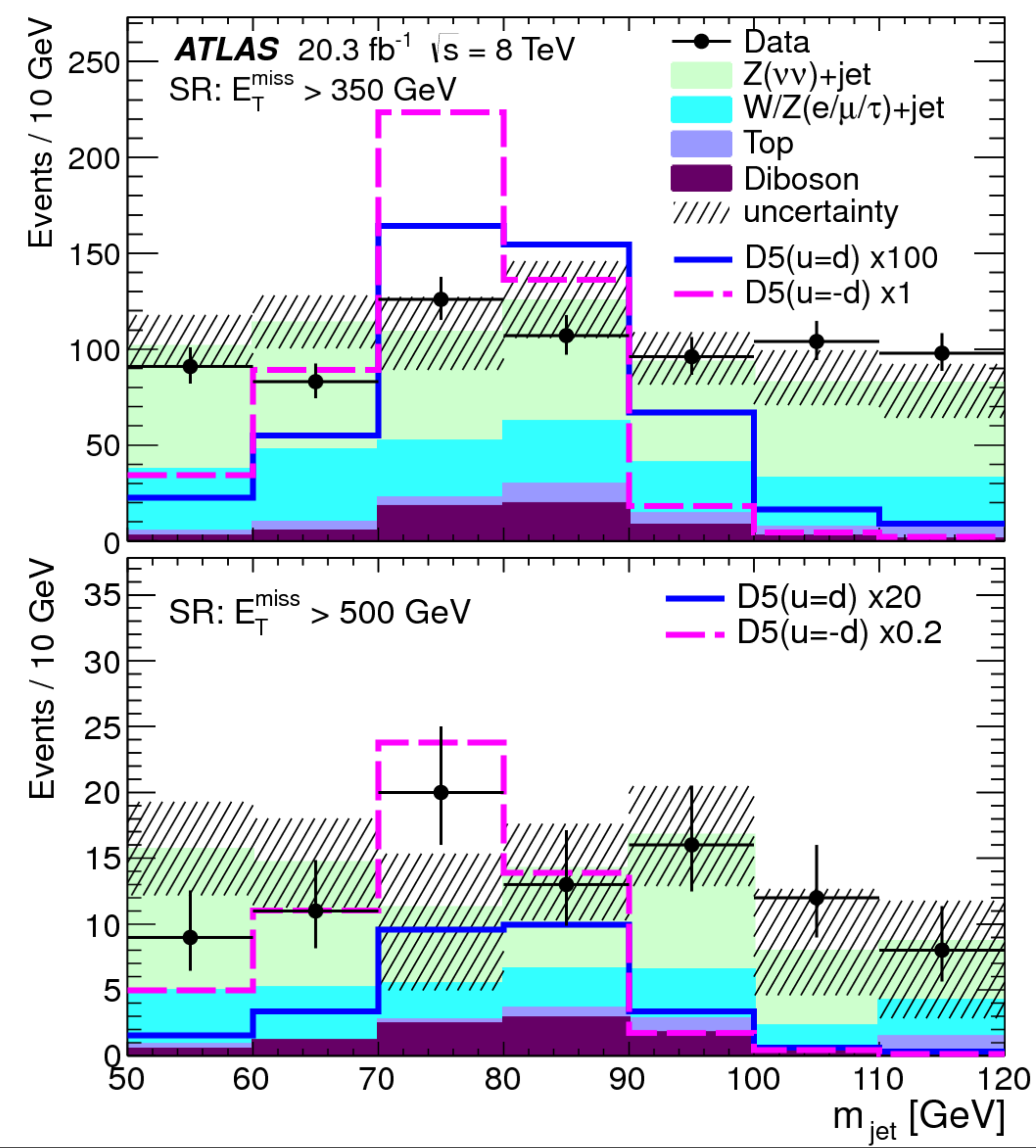
Total jet mass 50<Mjet<120 GeV

Sub-jet pT balance (√y > 0.4)

MET > 350, 500 GeV

Process	$E_T^{miss} > 350$ GeV	$E_T^{miss} > 500$ GeV
$Z \to \nu\bar{\nu}$	400^{+39}_{-34}	$54^{+7.5}_{-9.6}$
$W \to \ell^{\pm}\nu$, $Z \to \ell^{\pm}\ell^{\mp}$	210^{+20}_{-18}	$22^{+3.6}_{-4.6}$
WW, WZ, ZZ	$57^{+11}_{-8.0}$	$9.1^{+1.3}_{-1.1}$
$t\bar{t}$, single t	$39^{+9.9}_{-4.3}$	$3.7^{+1.7}_{-1.3}$
Total	710^{+48}_{-38}	$89^{+8.6}_{-12}$
Data	705	89





Mono-Z (leptonic)

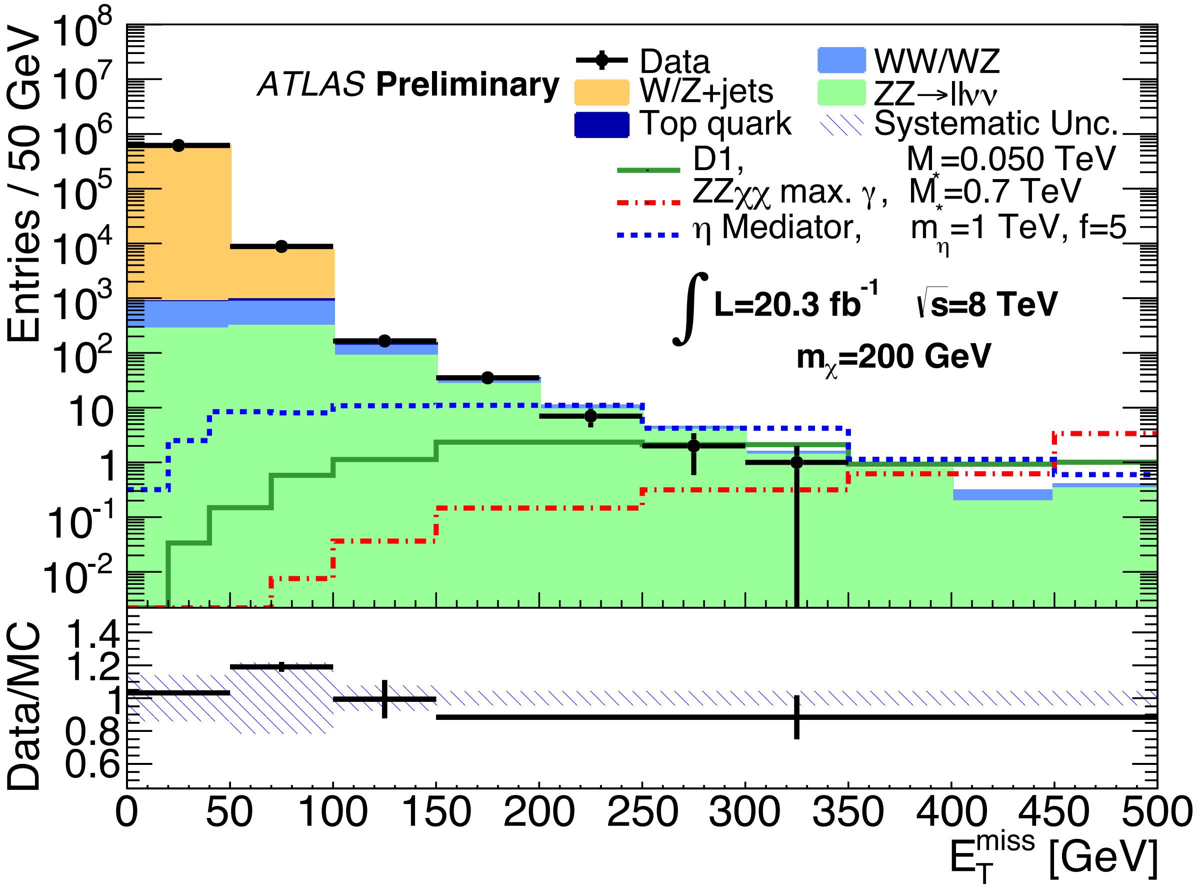
Tag with two opposite-charge leptons

- 76<mll<106 GeV
- **Δφ**(MET,ll)>2.5
- |pTll - MET|/pTll < 0.5
- |**η**ll| < 2.5

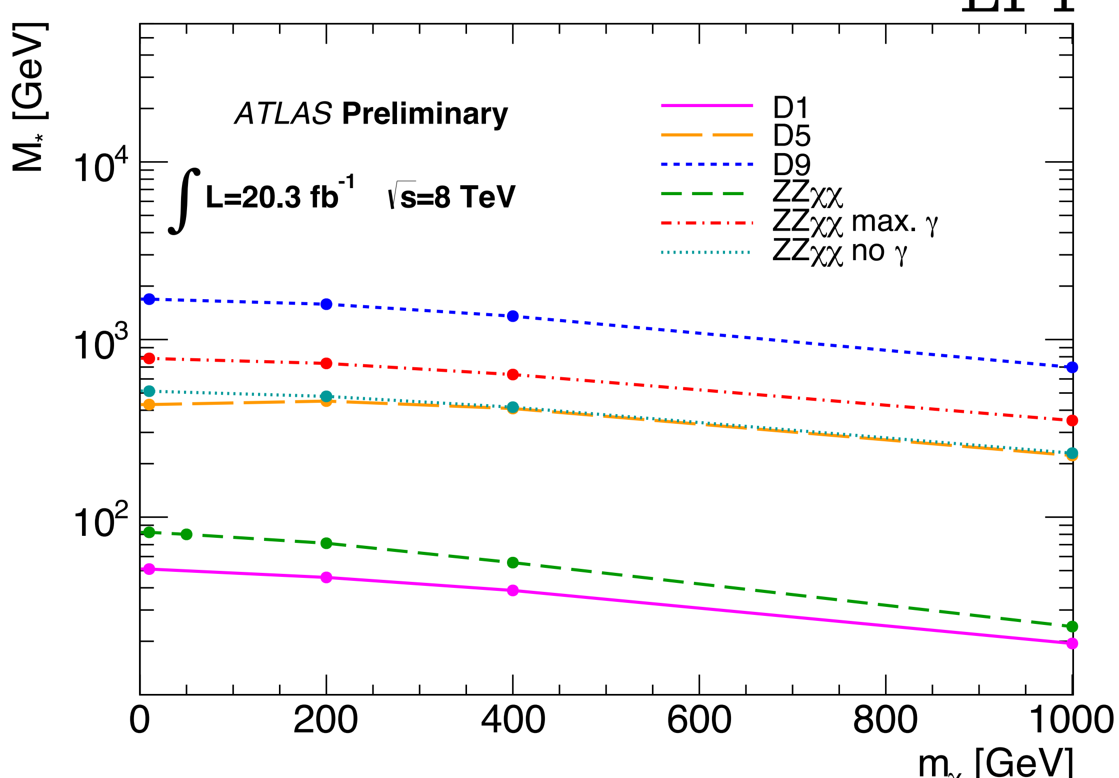
Main backgrounds data-driven

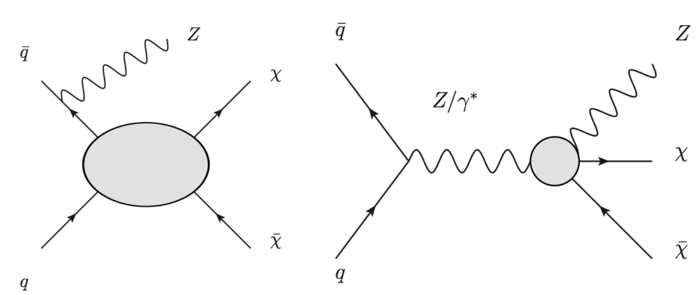
- Z+jets from ABCD in **Δφ**(MET,ll) and **η**ll

MET>150, 250, 350, 450 GeV

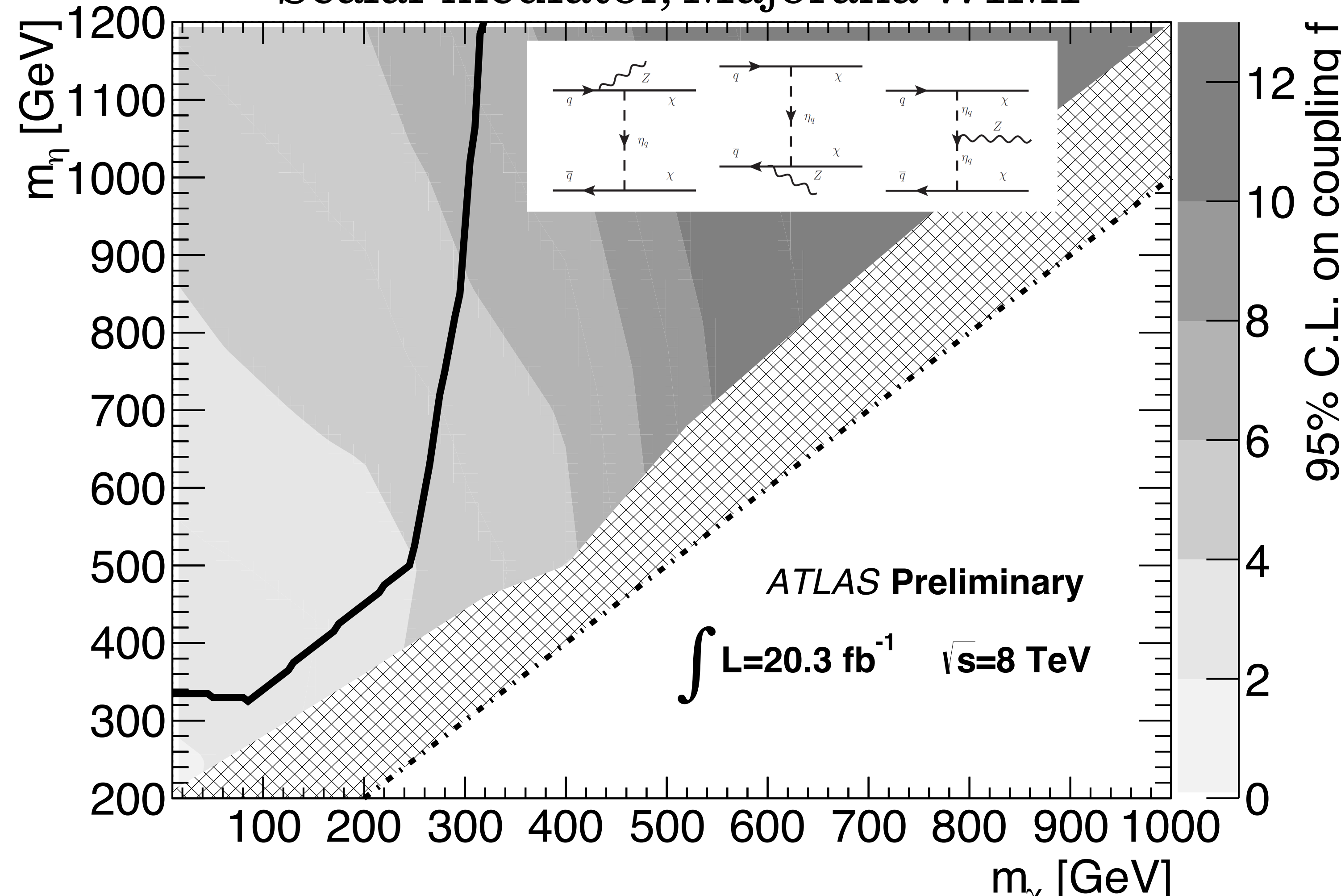


EFT





Scalar mediator, Majorana WIMP



Mono-Z (leptonic)

Tag with two opposite-charge leptons

76<mll<106 GeV

Δφ(ME

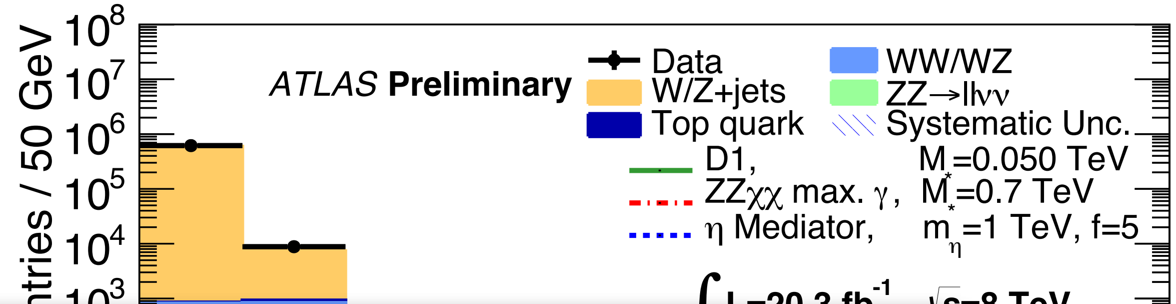
|pTll - M

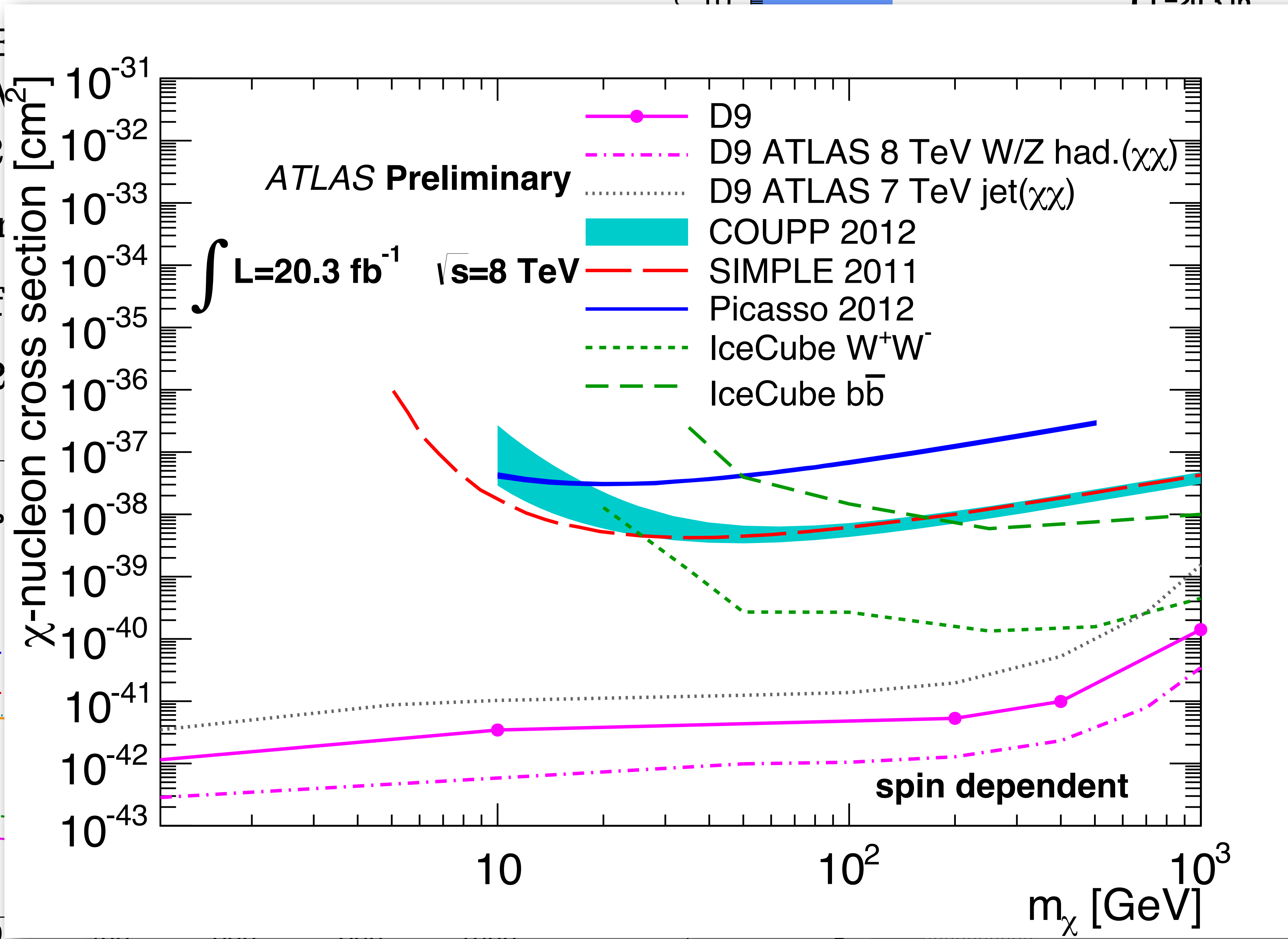
|ηll| < 2

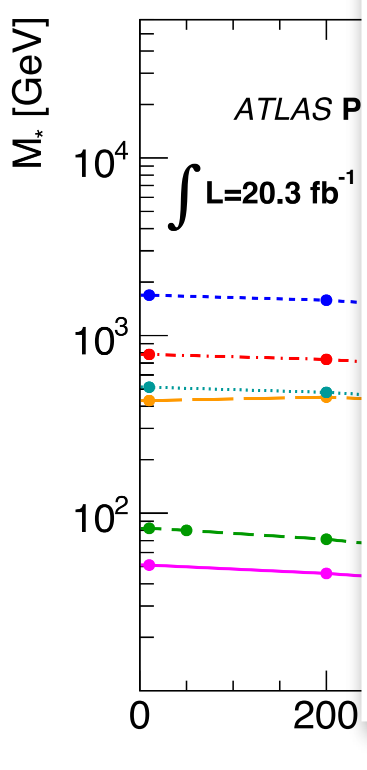
Main backgr

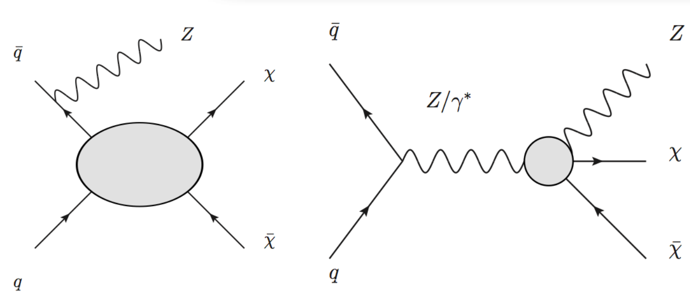
Z+jets f

MET>150, 2

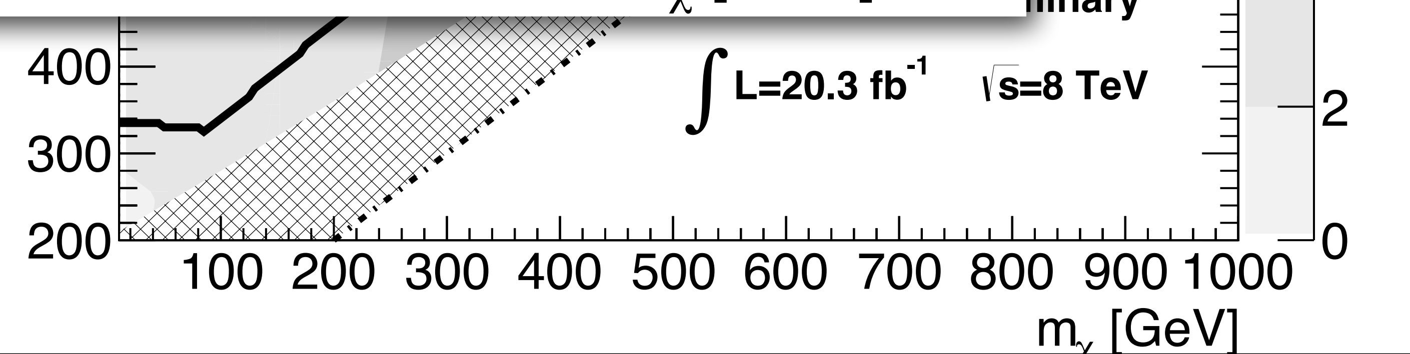








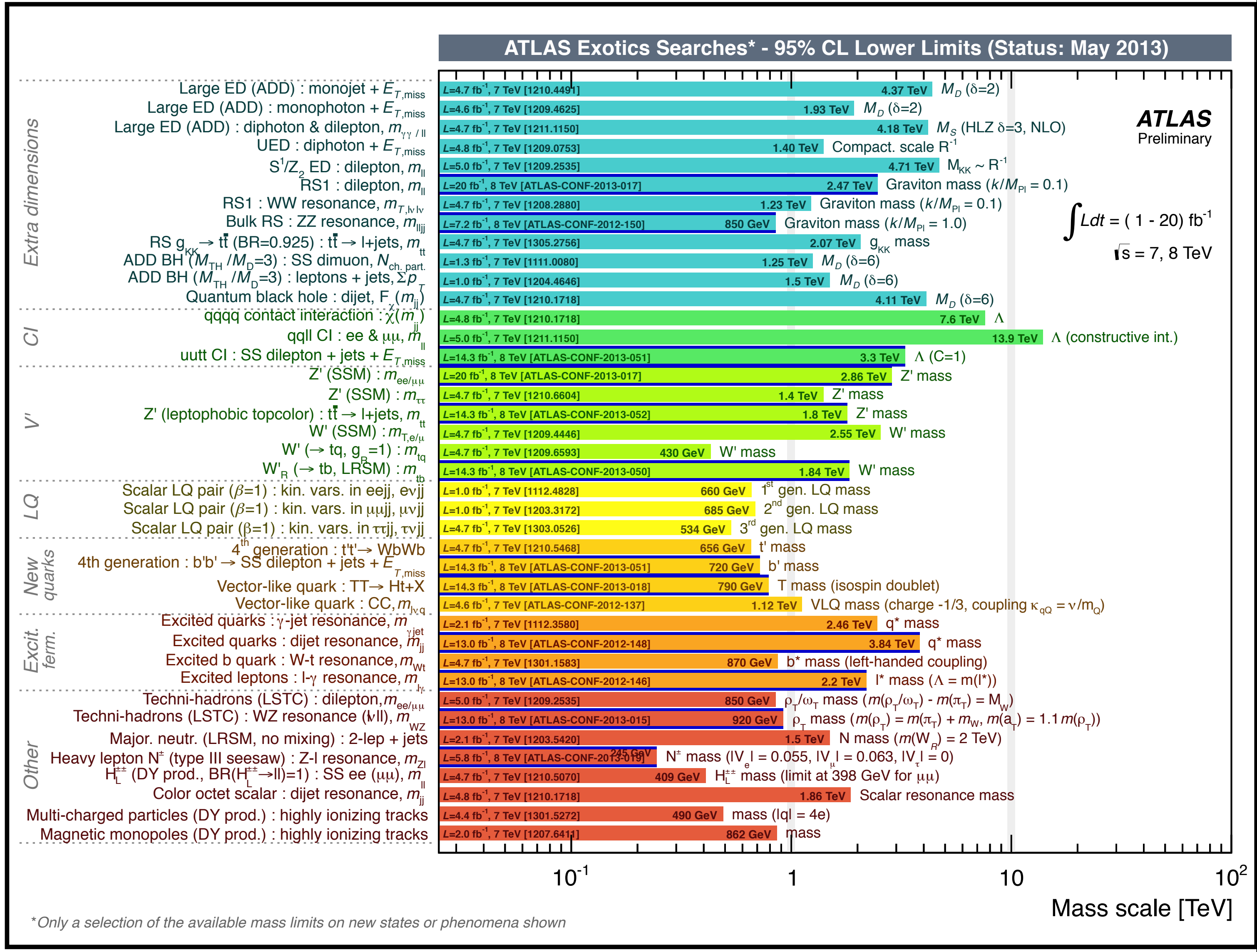
IMP



Outlook

ATLAS has many searches for (non-SUSY) BSM physics

- systematic, model-agnostic strategy
- wide range of final states, wide range of models



No excesses yet observed in Run I analyses

- analyses of 8 TeV data continuing

Prospects for Run II are excellent

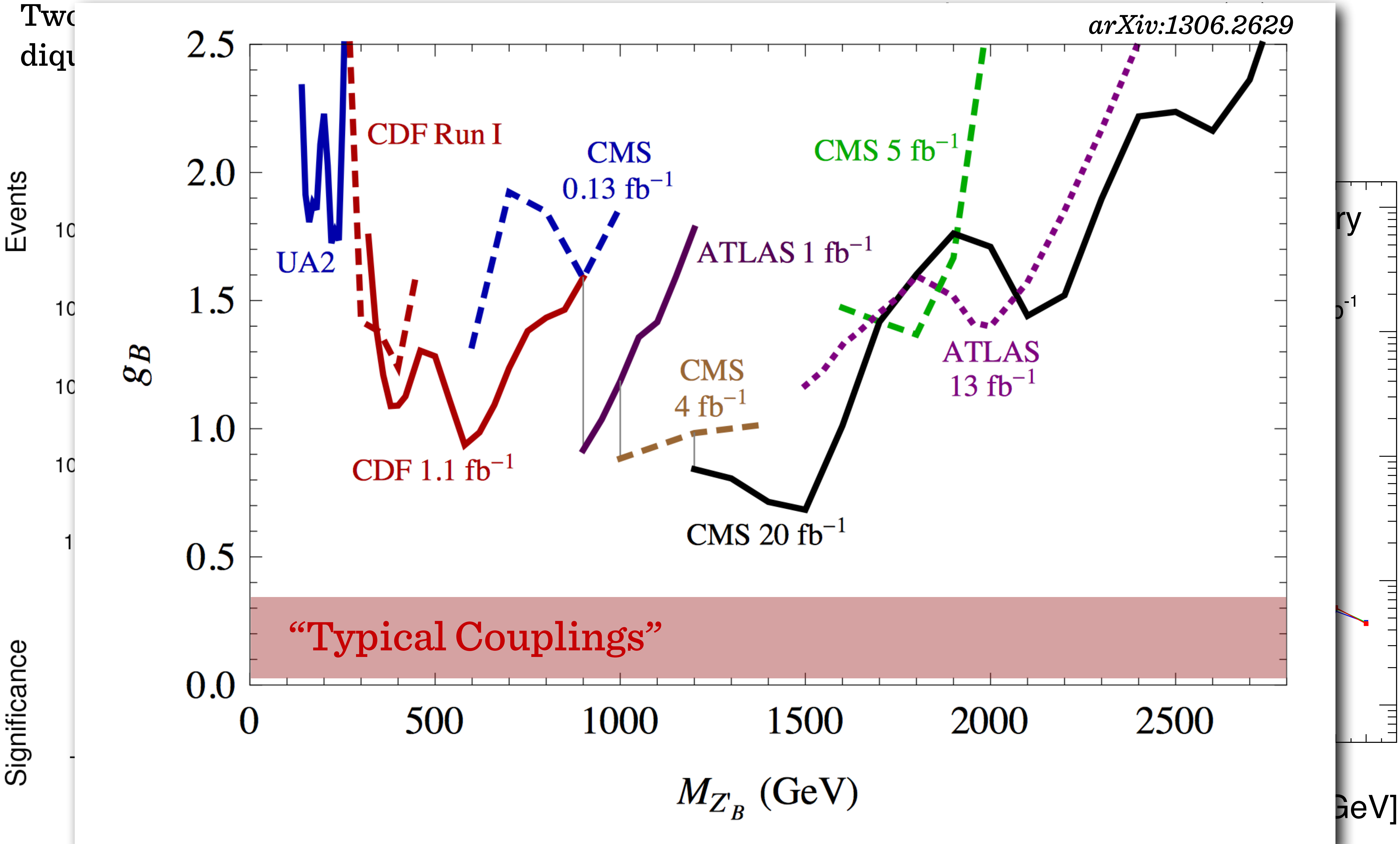
- large increase in sqrt(s) => large increase in effective luminosity to produce heavy objects
- large increase in luminosity => continue to constrain low rate processes at lower masses

Dijet resonances

ATLAS-CONF-2012-148

BumpHunt on smooth parameterization of dijet mass distribution

Two
diqu



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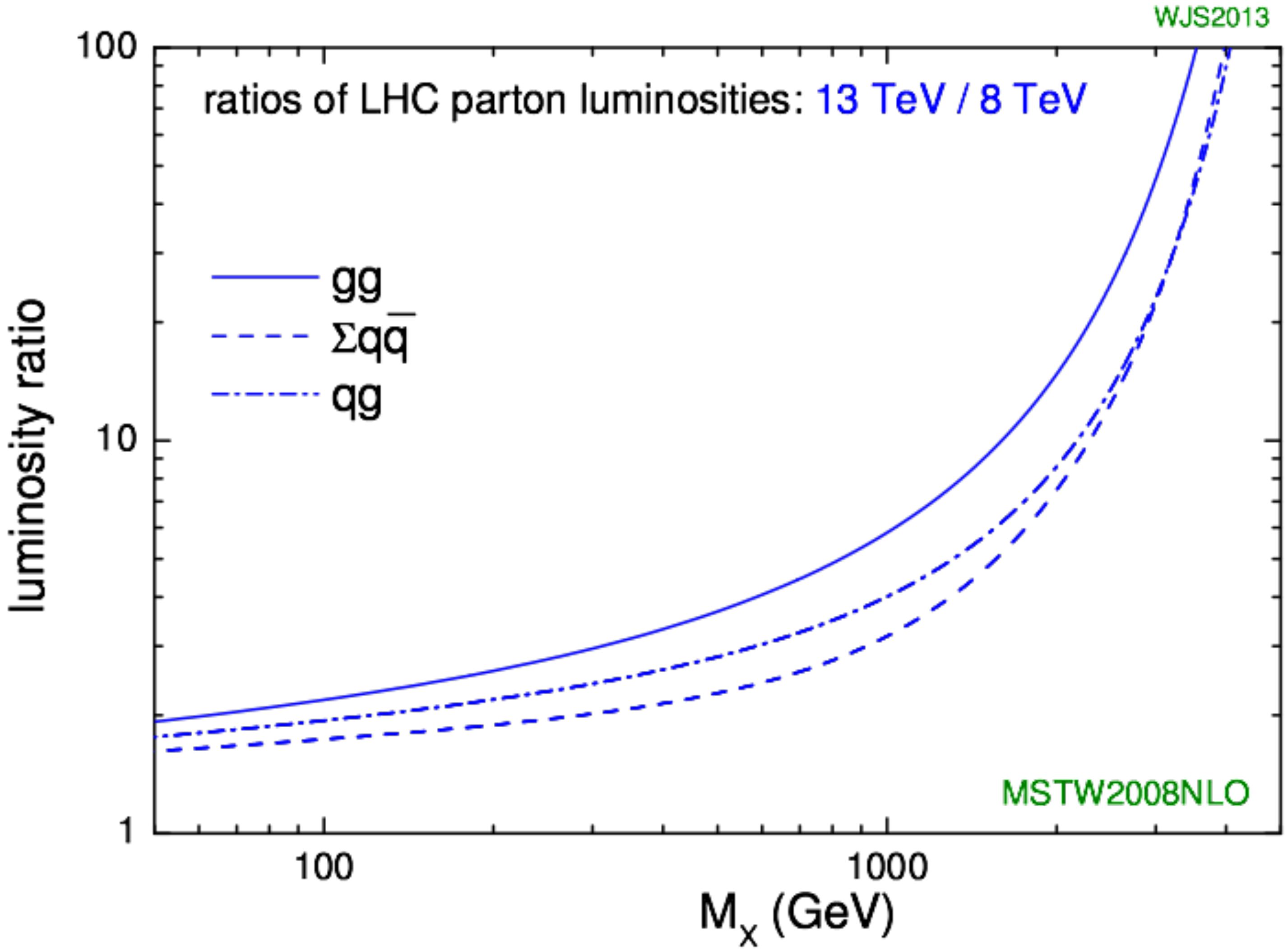
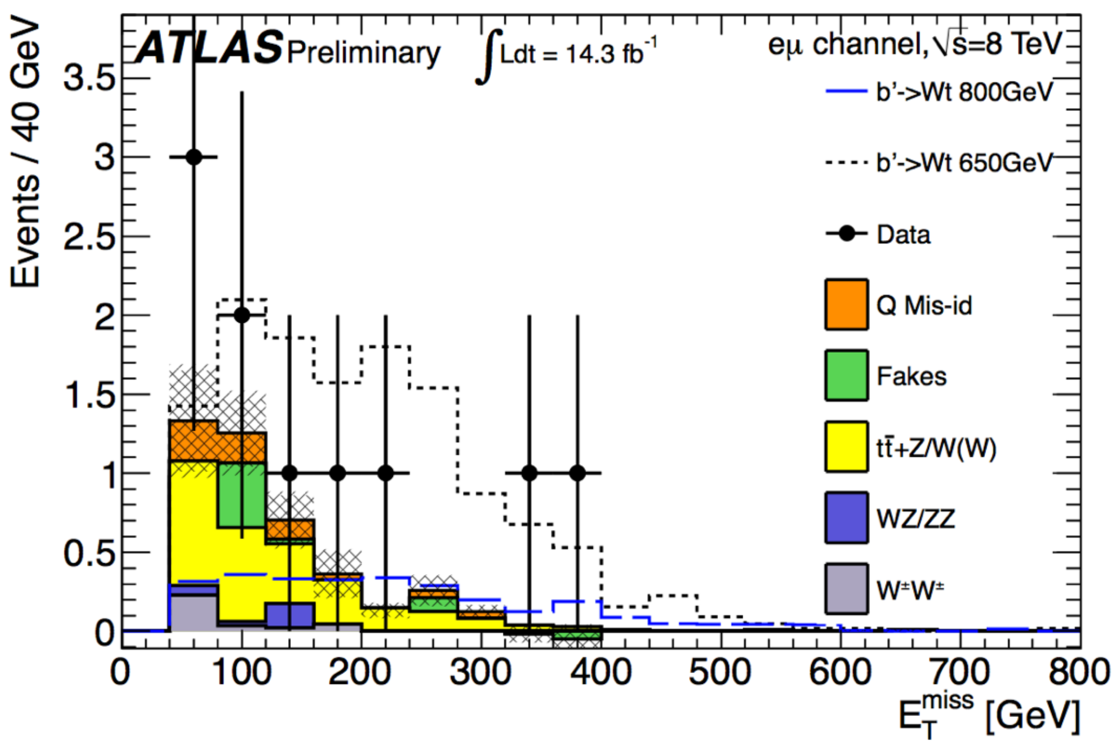


http://www.hep.phy.cam.ac.uk/~wjs/plots/plots.html

Additional Slides

Same-charge leptons + X

ATLAS-CONF-2013-051



Excludes:
$m_{b'} < 0.72$ TeV (100% BR to Wt)
$m_B < 0.59$ TeV (singlet model)
$m_T < 0.54$ TeV (singlet model)
ss top production rate > 0.21 pb
SM 4t production > 85 pb
$m_{sgluon} < 0.8$ TeV
$m_{KKphoton} < 0.9$ TeV (2UED)